Approved By:

Work Plan Manager 8/12/92 (Date)

M. B Smith 8/13/92
Division Manager (Date)

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LIST OF ACRONYMS

AEC	Atomic Energy Commission
AIP	Agreements in Principle
ARAR	Applicable or Relevant and Appropriate Requirement
AWQC	Ambient Water Quality Criteria
BCF	bioconcentration factor
BNA	base neutral extractables
BRA	Baseline Risk Assessment
CAA	Clean Air Act
CAD	Corrective Action Decision
CCR	Colorado Code of Regulations
CDH	Colorado Department of Health
CDOW	Colorado Department of Wildlife
CEARP	Comprehensive Environmental Assessment and Response Program
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
CMS	Corrective Measures Study
COC	contaminants of concern
CRP	Community Relations Plan
CWA	Clean Water Act
CWQCC	Colorado Water Quality Control Commission
DMC	derived media concentrations
DOE	U.S. Department of Energy
DRCOG	Denver Regional Council of Governments
DQO	data quality objective
EE	Environmental Evaluation
EER	Environmental Evaluation Report
EEWP	Environmental Evaluation Work Plan
Eh	oxidation reduction potential
EIS	Environmental Impact Statement
EM	Environmental Management
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
ERDA	Energy Research and Development Administration
F	Fahrenheit
FIDLER	Field Instrument for Detection of Low-Energy Radiation
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FS	feasibility study
FSP	Field Sampling Plan
GC	gas chromatograph
GPR	ground-penetrating radar

LIST OF ACRONYMS
(continued)

GRRASP	General Radiochemistry and Routine Analytical Services Protocol
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HSL	Hazardous Substance List
HSP	Health and Safety Plan
IAG	Interagency Agreement
IHSS	Individual Hazardous Substance Site
IM	Interim Measure
IPPCD	Interim Plan for Prevention of Contaminant Dispersion
IRA	Interim Remedial Action
IRIS	Integrated Risk Information System
ITPH	Interceptor Trench Pump House
ITS	Interceptor Trench System
MATC	maximum allowable tissue concentration
MDL	Minimum detection limit
MCL	maximum contaminant level
NCP	National Contingency Plan
NPDES	National Pollutant Discharge Elimination System
OPWL	Original Process Waste Lines
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PA	Protected Area
PARCC	precision, accuracy, representativeness, completeness, and comparability
PCB	polychlorinated biphenyl
PCN	Procedure Change Notice
PID	photoionization detector
PQL	Practical Quantitation Limit
PRP	potentially responsible parties
QAA	Quality Assurance Addendum
QA/QC	quality assurance/quality control
QAPjP	Quality Assurance Project Plan
RAAMP	Radiological Ambient Air Monitoring Program
RAGS-EEM	Risk Assessment Guidance for Superfund-Environmental Evaluation Manual
RAS	Routine Analytical Service
RCRA	Resource Conservation and Recovery Act
RfD	risk reference dose
RFEDS	Rocky Flats Environmental Database System
RFI	RCRA Facility Investigation
RFP	Rocky Flats Plant
RI	remedial investigation (CERCLA)
RME	reasonable maximum exposure
RO	Reverse Osmosis
ROD	Record of Decision

LIST OF ACRONYMS
(continued)

RSP	respirable suspended particulate
SAS	Special Analytical Services
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act of 1986
SCS	Soil Conservation Service
SDWA	Safe Drinking Water Act
SEAM	Superfund Exposure Assessment Manual
SEP	Solar Evaporation Ponds
SOP	Standard Operating Procedure
SPHEM	Superfund Public Health Evaluation Manual
SSH&SP	Site Specific Health and Safety Plan
SWCS	Surface Water Control System
SWMU	Solid Waste Management Unit
TAL	Target Analyte List
TBC	To Be Considered
TCL	Target Compound List
TDS	total dissolved solids
THM	Total trihalomethanes
TIC	tentatively identified compound
TOC	total organic carbon
TSCA	Toxic Substances Control Act
USCS	United Soil Classification System
UV	ultraviolet
VOA	volatile organic analysis
VOC	volatile organic compound
WQCC	Water Quality Control Commission

**APPENDICES A THROUGH G
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Approved By:

8/12/92
Work Plan Manager (Date)

8/12/92
Division Manager (Date)

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1.0 INTRODUCTION

This document presents the Work Plan for the Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI)/Remedial Investigation (RI) for Operable Unit No. 4 (OU4) at the Rocky Flats Plant (RFP) in Jefferson County, Colorado.

This investigation is part of a comprehensive, phased program of site characterization, remedial investigations, feasibility studies, and remedial/corrective actions currently in progress at RFP. These investigations are pursuant to an Interagency Agreement (IAG) among the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the State of Colorado Department of Health (CDH) dated January 22, 1991 (U.S. DOE, 1991a). The IAG program developed by DOE, EPA, and CDH addresses RCRA and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) issues. Although the IAG requires general compliance with both RCRA and CERCLA, RCRA regulations apply to remedial investigations at OU4. In accordance with the IAG, the CERCLA terms "Remedial Investigation" and "Feasibility Study" as used in this document are considered equivalent to the RCRA terms "RCRA Facility Investigation" and "Corrective Measures Study" (CMS), respectively. Also in accordance with the IAG, the term

"Individual Hazardous Substance Site" (IHSS) is equivalent to the term "Solid Waste Management Unit" (SWMU).

As required by the IAG, this Phase I Work Plan addresses characterization of source materials and soils at OU4. A subsequent Phase II RFI/RI will investigate the nature and extent of surface water, ground water, and air contamination and evaluate potential contaminant migration pathways. This Phase I work plan addresses characterization of source materials and soil, including (1) surficial soils, (2) vadose zone materials, and (3) the Interceptor Trench (French Drain) System. Pond liner materials will be characterized for their effectiveness as a barrier for contaminant migration.

In this Work Plan, the existing information is summarized to characterize OU4, data gaps are identified, data quality objectives (DQOs) are established, and a Field Sampling Plan (FSP) is presented to characterize site physical features and define contaminant sources.

The Phase I RFI/RI will be conducted in accordance with the *Interim Final RCRA Facility Investigation (RFI) Guidance* (U.S. EPA, 1989a) and *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (U.S. EPA, 1988a). Existing data and the data generated by the Phase I RFI/RI will be used to begin developing and screening remedial alternatives and to estimate the risks to human health and the environment posed by sources within OU4.

1.1 ENVIRONMENTAL RESTORATION PROGRAM

The Environmental Restoration (ER) Program, designed for investigation and cleanup of environmentally contaminated sites at DOE facilities, is being implemented in five phases. Phase 1 (Installation Assessment) includes preliminary assessments and site inspections to assess potential environmental concerns. Phase 2 (Remedial Investigations) includes planning and implementation of sampling programs to delineate the magnitude and extent of contamination at specific sites and evaluate potential contaminant migration pathways. Phase 3 (Feasibility Studies) includes evaluation of remedial alternatives and development of remedial action plans to mitigate environmental problems identified in Phase 2 as needing correction. Phase 4 (Remedial Design/Remedial Action) includes design and implementation of site-specific remedial actions selected on the basis of Phase 3 feasibility studies. Phase 5 (Compliance and Verification) includes monitoring and performance assessments of remedial actions as well as verification and documentation of the adequacy of remedial actions carried out under Phase 4. Phase 1 has been completed at the Rocky Flats Plant (U.S. DOE, 1986b), and Phase 2 is currently in progress for OU4.

1.2 WORK PLAN OVERVIEW

This Work Plan presents an evaluation and summary of previous data and investigations, defines data quality objectives and data needs based on that evaluation, specifies Phase I RFI/RI tasks, and presents the FSP for the Phase I RFI/RI.

Section 2.0 (Site Characterization) presents a comprehensive review and analysis of available historical information, previous site investigations, recently published reports, available data, and past and present activities pertinent to OU4. Included in Section 2.0 are characterization results for site geology and hydrology as well as the known nature of contamination in soils, ground water, and surface water. Additionally, Section 2.0 presents a conceptual model for contaminant migration and exposure based on site physical characteristics and available information regarding the nature and extent of contamination. Section 3.0 presents potential sitewide Applicable or Relevant and Appropriate Requirements (ARARs), as required by the IAG, and a discussion of their application to the RFI/RI activities at OU4. Section 4.0 discusses the DQOs and work plan rationale for the Phase I RFI/RI. Section 5.0 specifies tasks to be performed for the Phase I RFI/RI. The schedule for performance of Phase I RFI/RI activities is presented in Section 6.0. Section 7.0 presents the FSP to meet the objectives presented in Section 4.0. The Baseline Human Health Risk Assessment Plan is discussed in Section 8.0, and the Environmental Evaluation Work Plan (EEWP) is discussed in Section 9.0. The site-specific Quality Assurance Addendum (QAA) for OU4 is discussed in Section 10.0. Section 11.0 presents the Standard Operating Procedures (SOPs) and Procedure Change Notices (PCNs) for performing the field work.

The appendices contain available supporting information and data used to characterize the physical setting and contamination at OU4. Supporting information includes facility engineering drawings obtained from EG&G Rocky Flats, Inc. (EG&G). Supporting analytical information was obtained from existing reports and the EG&G Rocky Flats Environmental Database System (RFEDs). These data are in the process of being validated in accordance with EG&G Environmental Management (EM) Program Quality Assurance (QA) procedures. As of early 1991, only a small fraction of OU4 soils analytical data have been validated; these data are identified in the appendices by a qualifier adjacent to each datum. The qualifier "V" means the datum is valid, "A" means the datum is acceptable with qualifications (breach of QA), and "R" means the datum is rejected. Data were rejected because (1) sampling/analytical protocol did not conform to significant aspects of the QA/QC Plan (Rockwell International, 1989a) or (2) there is insufficient documentation to demonstrate conformance with these procedures. These data, at best, can be considered only qualitative measures of the analyte concentrations. The appendices also contain data from pond sludge and liquid sampling performed by Weston and summarized by Dames & Moore. These data are of significantly improved quality.

1.3 REGIONAL AND PLANT SITE BACKGROUND INFORMATION

The following subsections provide general information on RFP and the surrounding region, including RFP history, regional land use and population data, and site conditions. Site-specific conditions at OU4 are addressed in Section 2.0.

1.3.1 Facility Background and Plant Operations

RFP is a government-owned, contractor-operated facility, which is part of the nationwide Nuclear Weapons Complex. The plant was operated for the U.S. Atomic Energy Commission (AEC) from its inception in 1951 until the AEC was dissolved in January 1975. At that time, responsibility for the plant was assigned to the Energy Research and Development Administration (ERDA), which was succeeded by DOE in 1977. Dow Chemical U.S.A., an operating unit of the Dow Chemical Company, was the prime operating contractor of the facility from 1951 until June 30, 1975. Rockwell International was the prime contractor responsible for operating the Rocky Flats Plant from July 1, 1975, until December 31, 1989. EG&G Rocky Flats, Inc. became the prime contractor at RFP on January 1, 1990.

Operations at RFP consist of fabrication of nuclear weapons components from plutonium, uranium, and other nonradioactive metals (principally beryllium and stainless steel). Parts made at the plant are shipped elsewhere for assembly. In addition, the plant reprocesses components after they are removed from obsolete weapons for recovery of plutonium. Other activities at RFP include research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics. Both radioactive and nonradioactive wastes are generated in the production process. Current waste handling practices involve on-site and off-site recycling of hazardous materials, on-site storage of hazardous and radioactive mixed wastes, and off-site disposal of solid radioactive materials at another DOE facility. However, RFP operating procedures historically included both on-site storage and disposal of hazardous, radioactive, and radioactive mixed wastes. Preliminary assessments under the EM Program identified some of the past on-site storage and disposal locations as potential sources of environmental contamination.

1.3.2 Previous Investigations

Various site-wide studies have been conducted at RFP to characterize environmental media and to assess the extent of radiological and chemical contaminant releases to the environment. The investigations performed prior to 1986 were summarized by Rockwell International (1986a) and include the following:

1. Detailed description of the regional geology (Malde, 1955; Spencer, 1961; Scott, 1960, 1963, 1970, 1972, and 1975; Van Horn, 1972 and 1976; Dames and Moore, 1981; and Robson et al., 1981a and 1981b)

2. Several drilling programs beginning in 1960 that resulted in construction of approximately 60 monitoring wells by 1982

3. An investigation of surface water and ground water flow systems by the U.S. Geological Survey (Hurr, 1976)

4. Environmental, ecological, and public health studies that culminated in an Environmental Impact Statement (U.S. DOE, 1980)

5. A summary report on ground water hydrology using data from 1960 to 1985 (Hydro-Search, Inc., 1985)

6. A preliminary electromagnetic survey of the plant perimeter (Hydro-Search, Inc, 1986)

7. A soil-gas survey of the plant perimeter and buffer zone (Tracer Research, Inc., 1986)

8. Routine environmental monitoring programs addressing air, surface water, ground water, and soils (Rockwell International, 1975 through 1985, and 1986b)

In 1986, two major investigations were completed at the plant. The first was the DOE Comprehensive Environmental Assessment and Response Program (CEARP) Phase 1 Installation Assessment (U.S. DOE, 1986b), which included analyses and identification of current operational activities, active and inactive waste sites, current and past waste management practices, and potential environmental pathways through which contaminants could be transported. CEARP was later succeeded by the ER Program. A number of sites that could potentially have adverse impacts on the environment were identified. These sites were designated as solid waste management units (SWMUs) by Rockwell International (1987a). In accordance with the IAG, SWMUs are now designated as IHSSs, which were divided into three categories:

1. Hazardous substance sites that will continue to operate and need a RCRA operating permit

2. Hazardous substance sites that will be closed under RCRA interim status

3. Inactive substance sites that will be investigated and cleaned up under Section 3004(u) of RCRA or CERCLA

The second major investigation completed at the plant in 1986 involved a hydrogeologic and hydrochemical characterization of the plant site. Plans for this study were presented by Rockwell International (1986c and 1986d), and study results were reported by Rockwell International (1986e).

Investigation results identified areas considered to be significant contributors to environmental contamination.

1.3.3 Physical Setting

1.3.3.1 Location

RFP is located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 1-1). Other surrounding cities include Boulder, Westminster, and Arvada, all of which are located less than 10 miles to the northwest, east, and southeast, respectively. The plant consists of approximately 6,550 acres of federal land in Sections 1 through 4 and 9 through 15 of T2S, R70W, 6th Principal Meridian. In general, plant buildings are located within a protected central area site of approximately 400 acres, and surrounded by a buffer zone of approximately 6,150 acres.

RFP is bounded on the north by State Highway 128, on the east by Jefferson County Highway 17, (also known as Indiana Street), on the south by agricultural and industrial properties and Highway 72, and on the west by State Highway 93 (Figure 1-1).

1.3.3.2 Topography

RFP is located along the eastern edge of the southern Rocky Mountain region immediately east of the Colorado Front Range. The plant site is located on a broad, eastward-sloping pediment that is capped by alluvial deposits of Quaternary age (Rocky Flats Alluvium). The pediment surface has a fan-like form, with its apex and distal margins approximately 2 miles east of RFP. The tops of alluvial-covered pediments are nearly flat but slope gently eastward at 50 to 100 feet per mile (EG&G, 1991a). At RFP, the pediment surface is dissected by a series of east-northeast trending stream-cut valleys. The valleys containing Rock Creek, North and South Walnut Creeks, and Woman Creek lie 200 to 250 feet below the level of the older pediment surface. These valleys are incised into the bedrock underlying alluvial deposits, but most bedrock is concealed beneath colluvial material accumulated along the gentle valley slopes. The combined effects of stream-cut topographic relief and the shallow dip of the bedrock units beneath RFP suggest a potentially shallow depth to the Laramie formation in the valley bottoms.

1.3.3.3 Meteorology

The area surrounding RFP has a semiarid climate characteristic of much of the central Rocky Mountain region. Based on precipitation averages recorded between 1953 and 1976, the mean annual precipitation at the plant is 15 inches. Approximately 40 percent of the precipitation falls during the spring season, much of it as wet snow. Thunderstorms (June to August) account for an additional 30 percent of the annual precipitation. Autumn and winter are drier seasons, accounting for 19 and 11 percent of the annual precipitation, respectively. Snowfall averages 85 inches per year, falling from October through May (U.S. DOE, 1980).

Winds at RFP, although variable, are predominantly from the west-northwest. Stronger winds occur during the winter, and due to its location near the Front Range the area occasionally experiences Chinook winds with gusts up to 100 miles per hour. The canyons along the Front Range tend to channel the air flow during both up-slope and downslope conditions, especially when there is strong atmospheric stability (U.S. DOE, 1980).

Rocky Flats meteorology is strongly influenced by the diurnal cycle of mountain and valley breezes. Two dominant flow patterns exist, one during daytime conditions and one at night. During daytime hours, as the earth heats, air tends to flow toward the higher elevations (up-slope). During up-slope conditions air flow generally moves up the South Platte River Valley and then enters the canyons into the Front Range. After sunset, the air against the mountain side is cooled and begins to flow toward the lower elevations (downslope). During downslope conditions, air flows down the canyons of the Front Range onto the plains (e.g., Hodgin, 1983 and 1984; and U.S. DOE, 1986b).

Temperatures at RFP are moderate. Extremely warm or cold weather is usually of short duration. On average, daily summer temperatures range from 55 to 85 degrees Fahrenheit (°F), and winter temperatures range from 20 to 45°F. Temperature extremes recorded at the plant range from 102°F on July 12, 1971, to -26°F on January 12, 1963. The 24-year daily average maximum temperature for the period 1952 to 1976 is 76°F, the daily minimum is 22°F, and the average mean is 50°F. Average relative humidity is 46 percent (U.S. DOE, 1980).

Review of historical climatological data for RFP has indicated that some of the data are invalid under current quality standards. 1989 and 1990 RFP monthly and annual environmental monitoring reports prepared by EG&G contain climatological data that have been validated under current quality assurance protocol.

1.3.3.4 Surface Water Hydrology

Three intermittent streams that flow generally from west to east drain the RFP area. These drainages are Rock Creek, Walnut Creek, and Woman Creek (Figure 1-2).

Rock Creek drains the northwestern corner of the buffer zone and flows northeastward through the buffer zone to its off-site confluence with Coal Creek. Rock Creek is peripheral to the RFP facility, and is not known to have been impacted by RFP activities. North and South Walnut Creeks and an unnamed tributary drain the northern portion of the plant complex. These three forks of Walnut Creek join in the buffer zone and flow to Great Western Reservoir approximately 1 mile east of the confluence. Flow is diverted around Great Western Reservoir into Big Dry Creek via the Broomfield Diversion Ditch. Rock Creek, North and South Walnut Creeks, and the unnamed tributary are intermittent streams. Flow occurs in these streams only after precipitation events and spring snowmelt. An east-west trending interfluve separates Walnut Creek from Woman Creek. Woman Creek drains the southern Rocky Flats buffer zone and flows eastward into Mower Reservoir.

The South Interceptor Ditch is located between the plant and Woman Creek. The South Interceptor Ditch collects runoff from the southern portion of the plant complex and diverts it to pond C-2, where it is monitored in accordance with RFP National Pollutant Discharge Elimination System (NPDES) permit.

1.3.3.5 Ecology

A variety of vegetation is found within the buffer zone surrounding RFP. Included are species of flora representative of tall-grass prairie, short-grass plains, lower montane, and foothill ravine regions. Riparian vegetation exists along the site's drainages and wetlands. None of these vegetative species present at RFP have been reported to be on the endangered species list (EG&G, 1991m). Since acquisition of RFP property, vegetative recovery has occurred, as evidenced by the presence of disturbance-sensitive grass species such as big bluestem (*Andropogon gerardii*) and side oats grama (*Bouteloua curtipendula*) (U.S. DOE, 1980).

The fauna inhabiting the RFP and its buffer zone consists of species associated with western prairie regions. The most common large mammal is the mule deer (*Odocoileus hemionus*), with an estimated 100 to 125 permanent residents. There are a number of small carnivores, such as the coyote (*Canis latrans*), red fox (*Vulpes fulva*), striped skunk (*Mephitis mephitis*), and long-tailed weasel (*Mustela frenata*). Small herbivores can be found throughout the plant complex and buffer zone, including species such as the pocket gopher (*Thomomys talpoides*), cottontail (*Sylvilagus sp.*), white-tailed jackrabbit (*Lepus townsendii*), and the meadow vole (*Microtus pennsylvanicus*) (U.S. DOE, 1980).

Commonly observed birds include western meadowlarks (*Sturnella neglecta*), horned larks (*Eremophila alpestris*), mourning doves (*Zenaidura macroura*), and vesper sparrows (*Pooecetes gramineus*), western kingbirds (*Tyrannus vociferans*), black-billed magpies (*Pica pica*), American robins (*Turdus migratorius*), and yellow warblers (*Dendroica magnolia*). Killdeer (*Charadrius vociferus*), and red-winged black birds (*Agelaius phoeniceus*) are seen in areas adjacent to ponds. Mallards (*Anas platyrhynochos*) and other ducks (*Anas sp.*) frequently nest and rear young on several of the ponds. Common birds of prey in the area include marsh hawks (*Circus cyaneus*), red-tailed hawks (*Buteo jamaicensis*), ferruginous hawks (*Buteo regalis*), rough-legged hawks (*Buteo lagopus*), and great horned owls (*Bubo virginianus*) (U.S. DOE, 1980).

Bull snakes (*Pituophis melanoleucus*) and rattlesnakes (*Crotalus sp.*) are the most frequently observed reptiles. Eastern yellow-bellied racers (*Coluber constrictor flaviventris*) have also been seen. The eastern short-horned lizard (*Phrynosoma douglassi brevirostre*) has been reported on the site, but these and other lizards are not commonly observed. The western painted turtle (*Chrysemys* *picta*) and the western plains garter snake (*Thamnophis radix*) are found in and around many of the ponds (U.S. DOE, 1980).

Two procedures which concern identification and management of threatened and endangered species at RFP currently are being prepared by the EG&G National Environmental Policy Act (NEPA) Group. These are the draft "Identification and Reporting of Threatened and Endangered and Special Concern Species," administrative procedure NEPA.12, Rev. 0, and the draft "Protection of Threatened and Endangered and Special Concern Species," operations procedure FO.21, Rev. 0.

1.3.3.6 Surrounding Land Use and Population Density

The population, economics, and land use of areas surrounding RFP are described in a 1989 Rocky Flats vicinity demographics report prepared by DOE (U.S. DOE, 1990b). This report divides general use of areas within 0 to 10 miles of RFP into residential, commercial, industrial, parks and open spaces, agricultural and vacant, and institutional classifications, and also considers current and future land use near RFP.

The majority of residential use within 5 miles of RFP is located immediately northeast, east, and southeast of the plant. The 1989 population distribution within areas up to 5 miles from RFP is illustrated in Figure 1-3. Commercial development is concentrated near residential developments north and southwest of Standley Lake as well as around Jefferson County Airport, approximately 3 miles northeast of RFP. Industrial land use within 5 miles of the plant is limited to quarrying and mining operations. Open space lands are located northeast of RFP near the City of Broomfield and in small parcels adjoining major drainages and small neighborhood parks in the cities of Westminster and Arvada. Standley Lake is surrounded by Standley Lake Park. Irrigated and non-irrigated croplands, producing primarily wheat and barley, are located northeast of RFP near the cities of Broomfield, Lafayette, and Louisville; north of RFP near Louisville and Boulder; and in scattered parcels adjacent to the eastern boundary of the plant. Several horse operations and small hay fields are located south of RFP. The demographic report characterizes much of the vacant land adjacent to RFP as rangeland (U.S. DOE, 1990b).

Future land use in the vicinity of RFP most likely involves continued urban expansion, increasing the density of residential, commercial, and perhaps industrial land use in the areas. The expected trend in population growth in the vicinity of RFP is also addressed in the DOE demographic study (U.S. DOE, 1990b). The report considers expected variations in population density by comparing the current (1989) setting to population projections for the years 2000 and 2010. A 21-year profile of projected population growth in the vicinity of RFP can thus be examined. DOE's projections are based primarily on long-term population projections developed by the Denver Regional Council of Governments (DRCOG). Expected population density and distribution around RFP for the years 2000 and 2010 are shown in Figures 1-4 and 1-5, respectively.

1.3.3.7 Regional Geology

RFP is located on a broad, eastward-sloping pediment surface along the western edge of the Denver Basin (Figure 1-6). The area is underlain by more than 10,000 feet of Pennsylvanian to Upper Cretaceous sedimentary rocks that have been locally folded and faulted. Along the foothills west of RFP, sedimentary strata are steeply east-dipping to overturned. In the western buffer zone, Upper Cretaceous sandstones of the Laramie formation make up an east-dipping (45° to 55°) hogback that strikes approximately north-northwest (Scott, 1960). Immediately west of the plant, steeply dipping sedimentary strata abruptly flatten to less than 2 degrees under and east of RFP (EG&G, 1991a). The sedimentary bedrock is unconformably overlain by Quaternary alluvial gravels that cap pediment surfaces of several distinct ages (Scott, 1965). See Figure 1-6.

Figure 1-7 shows the local stratigraphic section for the Rocky Flats area. Upper Cretaceous bedrock units directly underlying RFP and pertinent to plant site hydrogeology include, in descending stratigraphic order, the Arapahoe formation, the Laramie formation, and the Fox Hills Sandstone. These bedrock units and the overlying surficial Quaternary Deposits units at RFP are described below.

Quaternary Deposits

The Quaternary Deposits in the RFP area (Figure 1-6) have been categorized into three types of pediment cover and four types of valley fill . The Rocky Flats, Verdos, and Slocum Alluviums represent pediment covers. The valley fill alluviums include the Louviers and the Broadway Alluviums. Additional recent alluvial valley fill deposits include the Piney Creek and Post Piney Creek Alluviums. These alluvial units have been correlated along the Front Range by their stratigraphic height above modern stream drainages (EG&G, 1991i).

The Rocky Flats Alluvium is the oldest alluvial deposit in the RFP area and consists of poorly sorted, angular to rounded, coarse gravels, sands, and gravelly clay. Caliche amounts vary from trace to abundant. The alluvium occurs about 250 to 380 feet above modern stream drainages (EG&G, 1991i). Dominant lithologies include Precambrian quartzite, schist, and gneiss deposited by Coal Creek. Thickness at the type locality just south of the RFP is 50 feet, and ranges between 10 and 90 feet (Machette, 1976).

The Verdos Alluvium consists of a sandy, cobbly to bouldery gravel, deposited by Ralston Creek (Machette, 1976). The thickness ranges from 15 to 35 feet, and it occurs at 200 to 250 feet above modern streams. The Slocum Alluvium is composed of well-stratified, clayey, coarse gravel and coarse sand and its thickness ranges between 10 and 90 feet. It occurs at 80 to 120 feet above modern streams (EG&G, 1991i).

The Louviers and the Broadway Alluviums are composed of coarse sand and cobbley gravel and range between 10 and 25 feet in thickness. The Louviers Alluvium forms well-developed terraces 40 to 80 feet above modern streams. The Broadway Alluvium forms terraces between 25 and 45 feet above modern streams and occurs in channels cut into the Louviers Alluvium (EG&G, 1991i).

The Pre-Piney Creek, the Piney Creek, and Post Piney Creek Alluviums represent the most recent deposits. The Pre-Piney Creek consist of silt and sand with pebbles lenses, the Piney Creek consists of clay, silt, sand, with some pebble beds, and the Post-Piney Creek consists of poorly consolidated, humic, fine-to medium-grained sandstone interbedded with a magnetite-rich sandstone (EG&G, 1991i).

Upper Cretaceous Deposits

Depositional environments east of the Front Range in the Late Cretaceous period were influenced by the Laramide Orogeny which resulted in the uplift of the Colorado Front Range Mountains. The uplift caused a regression of the Cretaceous Sea from the west to the east, resulting in a lateral progradation of Pierre Prodelta shales and siltstones, the Fox Hills delta front sandstones, the Laramie delta plain sandstones, claystones, and coals, and Arapahoe fluvial conglomerates, sandstones and claystones (Weimer, 1976).

The above-mentioned formations are relatively distinct, from a regional perspective, reflecting increasingly higher gradients of deposition with correspondingly higher energy facies. However, lateral and vertical variations in the depositional history of the Arapahoe Formation have been observed as a function of localized tectonic surges, creating the accumulation of higher energy, braided stream facies south of RFP in the Golden area, whereas lower energy, meandering stream facies occur in the RFP area. The Draft Final Geologic Characterization Report contains one interpretation of the sequence of deposition for the Laramie and Arapahoe formations. However, it presents two different interpretations for the depositional nature of the uppermost Arapahoe sandstones. The interpretations vary in the relative depositional gradient for the Arapahoe in the RFP area. The first interpretation assumes a single continuous meandering channel system, while the second interpretation assumes a system with multiple channels.

The gradational, transitional nature of the Laramie and Arapahoe formations makes the exact definition of the contact between the two formations difficult. A regional surface mapping project of the RFP area was conducted during 1991 as part of the site-wide Phase II Geologic Characterization efforts. Field criteria for the definition of Arapahoe sandstones included frosted, well-rounded, coarser quartz grains. However, in the subsurface, these characteristics have been observed in lower Arapahoe Formation sandstones, which were mapped as Laramie Formation during the field mapping effort. Site-wide geologic characterization investigations are continuing to resolve this issue (EG&G, 1991e).

The Arapahoe Formation is the uppermost bedrock unit underlying RFP and consists primarily as claystones and silty claystones in the RFP area. The Arapahoe Formation is approximately 150 feet thick in the center of RFP. At least five mappable sandstones have been identified within the formation. The Arapahoe Sandstone No. 1 outcrops occasionally and subcrops extensively in the RFP area. Its thickness varies between 0 and 27 feet. Its aerial extent has been mapped according to the two depositional interpretations discussed above and presented in the Draft Final Geologic Characterization Report (EG&G, 1991i).

The Arapahoe sandstones are very fine to medium grained, with some occasional conglomeratic lenses occurring. Weathered sandstones are pale orange, yellowish-gray, and dark yellowish-orange. Unweathered sandstones are light gray to olive-gray. The sandstones are typically interlayered with clay lenses and are lenticular in geometry. The dominant claystones and silty claystones are light to medium olive-gray and appear dark yellowish orange where weathered. Iron-oxide staining is common in the upper 20 feet of the sandstones (EG&G, 1991i).

The Laramie Formation consists of an upper claystone interval and a lower sandstone and coal interval and is approximately 800 feet thick. The upper Laramie Formation consists of silty claystones and siltstones, and fine-grained lenticular fluvial sandstones. The silty claystones are light olive gray to olive black, massive, occasionally sandy, and contain carbonaceous material. Siltstones are also carbonaceous, with iron oxide nodules and slickensides along fractures. The lower Laramie Formation consists of thick (up to 50 feet) sandstones and coal beds ranging from 2 to 8 feet thick. The sandstones are very fine to medium-grained.

The Fox Hills Formation averages 75 feet thick and consists of thick-bedded to massive, very fine to medium-grained feldspathic sandstone which is grayish-orange to light gray in color. The sandstones are interlayered with thin beds of siltstone and claystone (EG&G, 1991i).

1.3.3.8 Hydrogeology

The RFP is situated in a regional ground water recharge area. Ground water recharge occurs as infiltration of precipitation, primarily where bedrock outcrops in the western portion of the RFP, along the west limb of the monoclinal fold. Recharge also occurs as a result of seepage from streams, ditches, and ponds, and into subcropping bedrock. Locally, there are areas of discharge as well as recharge. Ground water discharges to streams and along slopes as seeps. Much of the ground water within the uppermost hydrostratigraphic unit becomes surface water or evaporates as it is discharged from the ground water system at seeps along slopes and in drainage valleys (EG&G, 1991i).

Unconfined ground water at the RFP occurs in the unconsolidated alluvial material. It includes the Rocky Flats Alluvium which is present on broad topographic highs and the Valley Fill Alluvium, present in modern stream drainages. Although the water depth is variable, it becomes shallower from west to east as the alluvial material thins. In the stream drainages, seeps are common at the base of the Rocky Flats Alluvium at the contact with the claystones of the Arapahoe and Laramie Formations and where individual Arapahoe Formation sandstones crop out (EG&G, 1991i). Generally, flow in unconfined ground water at RFP is to the east.

Generally, the ground water flows along the contact of the unconsolidated material and the Arapahoe Formation claystones in a downgradient direction to the east. The claystones have a low hydraulic conductivity, on the order of 1×10^{-7} centimeters per second (cm/s), effectively constraining much of the flow within the water table aquifer to the alluvial material above the alluvial/bedrock unconformity. Ground water in the sandstone units of the Arapahoe Formation occurs under confined conditions throughout most of the plant site. The exception to this is the occurrence of ground water in the subcropping units beneath the alluvial material. In this situation, the ground water exists under unconfined conditions. The Arapahoe No. 1 Sandstone subcrops frequently throughout the RFP area and therefore acts as an unconfined aquifer for a substantial portion of its occurrence. The lower sandstones of the Arapahoe Formation also subcrop at the unconformity, but in limited areas along valley slopes. The confining layers for the sandstones are the claystones and silty claystones of the Arapahoe Formation. The Arapahoe and the alluvial hydrostratigraphic units at RFP have relatively low hydraulic conductivities and, therefore, are not generally believed to be capable of producing economical amounts of water. The hydraulic conductivity of the Rocky Flats Alluvium and the Arapahoe No. 1 Sandstone is approximately 6 x 10^{-5} cm/s, as set forth in the Draft Final Ground Water Protection and Monitoring Plan, June 13, 1991. The lower Arapahoe sandstones have a hydraulic conductivity of approximately 10^{-6} cm/s.

Approved By:

0/12/92
Work Plan Manager (Date)

4/15/92
Division Manager (Date)

Effective Date: August 31, 1992

2.0 SITE CHARACTERIZATION

The Solar Evaporation Ponds (Solar Ponds) are located in the central portion of the RFP on the northeast side of the Protected Area (PA). The Solar Ponds Waste Management Unit, which is considered equivalent to Individual Hazardous Substance Site 101 (IHSS 101), consists of five surface impoundments; Ponds 207-A, 207-B North, 207-B Center, 207-B South, and 207-C. IHSS 101 is within the OU4 boundary (Figure 2-1). The area under investigation in this Phase I work plan includes the Solar Ponds and other areas and features which are considered pertinent to the characterization of OU4. The major features in the Solar Ponds area include the Solar Ponds, the Original Pond, the Interceptor Trench System (ITS) also known as the french drain system, and areas in the immediate vicinity of the Solar Ponds (Figure 2-2). Aerial photographs of the Solar Ponds area taken in June 1991 are included in Photographs 2-1 and 2-2.

2.1 REGULATORY HISTORY OF OU4 AND INTERIM RESPONSE ACTIONS

The Solar Ponds were first identified as a RCRA regulated unit in the summer of 1986. Shortly thereafter, an interim status closure plan for the Solar Ponds was prepared in accordance with a compliance agreement. A closure plan for the interim status closure of the Solar Evaporation Ponds was required pursuant to Part 265 of the Colorado Hazardous Waste Regulations (6 CCR) and Title

40, Part 265 of the Code of Federal Regulations (40 CFR). This closure plan was revised in 1987 and again in 1988.

In late 1986, Phase I of a comprehensive program of site characterizations, remedial investigations, feasibility studies and remedial/corrective actions began at RFP. These investigations were initiated pursuant to the DOE Comprehensive Environmental Assessment and Response Program (CEARP) and Compliance Agreement finalized by representatives of the DOE and the U.S. Environmental Protection Agency (EPA) on July 31, 1986. CEARP is now known as the Environmental Restoration (ER) Program. (EG&G Rocky Flats, 1991d).

On June 28, 1989, DOE and the State of Colorado entered into the Agreement in Principle (AIP). This document stated that certain contaminated sites (e.g., the solar ponds) at RFP require special and accelerated actions. The AIP specifies in part that DOE will expedite cleanup of the Solar Ponds in order to stem the flow of harmful contaminants into the ground water and soil.

On January 22, 1991, the DOE, EPA and the State of Colorado entered into a Federal Facility Agreement and Consent Order, commonly known as the Rocky Flats Interagency Agreement (IAG). The IAG establishes the work and schedule for the RCRA Facility Investigation/Remedial Investigation (RFI/RI) and Corrective Measures Study/Feasibility Study (CMS/FS) response process. OU4 is currently in the Phase I RFI/RI stage. Phase I requires the characterization of sources and soils.

In accordance with the IAG and to fulfill the intent of the AIP, OU4 (the Solar Ponds) is presently in an Interim Measure/Interim Remedial Action (IM/IRA) process. The current IM/IRA is part of the enabling action taken to facilitate waste removal operations, cleanout of the ponds, and eventually site closure. Changes to the operation of the Solar Ponds are required to allow the dewatering of liquids and removal of sludges from the ponds. The IM/IRA proposes an alternate means of storing water collected by the Interceptor Trench System (ITS), and a means to treat these collected waters and excess liquids currently contained in the Solar Ponds.

2.2 BACKGROUND AND PHYSICAL SETTING OF OU4

The Solar Ponds were constructed primarily to store and treat by evaporation low-level radioactive process wastes containing high nitrates, and neutralized acidic wastes containing aluminum hydroxide. During their use, these ponds are known to have received additional wastes such as sanitary sewage sludge, lithium metal, sodium nitrate, ferric chloride, lithium chloride, sulfuric acid, ammonium persulfates, hydrochloric acid, nitric acid, hexavalent chromium and cyanide solutions (Rockwell International, 1988a). Solvents and other organics have not been routinely discharged to the ponds. It was felt that organics would lead to algal growth which would diminish solar evaporation. However, low concentrations of solvents may have been present as a minor constituent in other aqueous wastes. The Original Pond was constructed in 1953 and used continuously until 1956, when its regular use was discontinued. Pond 207-A was placed in service in August 1956. Ponds 207-B North, Center, and South were placed in service in June 1960. Pond 207-C was constructed in 1970 to provide additional storage capacity and to allow the transfer and storage of liquids from the other ponds in order to perform pond repair work. The use of individual ponds has changed over time. Sludges from the Solar Ponds have been removed from time to time to implement repair work on the pond liners and as part of routine waste management activities. As the sludges were removed, they were mixed with Portland cement and solidified as a mixture of sludge and concrete (pondcrete) for shipment to an off-site low-level radioactive waste disposal site.

The routine placement of process waste material into the Solar Ponds ceased in 1986 because of changes in RFP waste treatment operations. Presently, Pond 207-A is nearly dry containing a small volume of intercepted seepage and ground water collected by the ITS. The 207-B ponds continue to be used for storage and treatment of intercepted water collected by the ITS. Pond 207-C continues to store and treat process waste.

Nitrite contamination of North Walnut Creek, located north of the Solar Ponds, was documented in the early 1970s. In response to this contamination, a series of trenches and sumps were installed north of the Solar Ponds during the period of 1971 to 1974. The trenches and sumps collected seepage and ground water, and were in operation until the 1980s when they were replaced by a more extensive french drain system (the ITS). The ITS is currently in use. Water collected by the ITS flows by gravity to the Interceptor Trench Pump House (ITPH). From there the water is currently pumped to Pond 207-B North. The current amount of intercepted seepage collected by the ITS is estimated to be approximately 4 million gallons per year.

Specific details concerning the construction and use of each pond, the trenches and the ITS are contained in subsequent sections. A summary of major events which have occurred at the Solar Ponds is included in Figure 2-3. Additional construction drawings are contained in the 1988 Solar Evaporation Ponds Closure Plan (Rockwell International, 1988a) and in Appendix A of this Work Plan.

2.2.1 The Original Pond

The Original Pond consisted of a clay lined impoundment, constructed in December 1953, in the vicinity of the existing Pond 207-C. Figure 2-2 shows the approximate location of the original and existing ponds. Photograph 2-3, taken in September 1956, also shows the Original Pond in relation to Pond 207-A. Photograph 2-3 is an easterly view from the west side of the Original Pond with Pond 207-A in the background. The Original Pond consisted of two cells which measured approximately 100 by 200 feet and 200 by 200 feet. The Original Pond was operated with both cells until 1956, when its regular use was discontinued. Based upon aerial photographs, one of the two cells may have contained liquids one or more times since 1963. Aerial photographs also indicate that the location of the Original Pond was regraded in 1970, during the construction of Pond 207-C. Soil from the area of the Original Pond may have been used in the construction of Pond 207-C. Additional drawings obtained from EG&G Facility Engineering are included in Appendix A of this Work Plan.

2.2.2 Solar Evaporation Pond 207-A

Pond 207-A was placed in service in August 1956. The original construction consisted of asphalt planking approximately 1/2-inch thick (Figure 2-4). Photograph 2-4, taken in May 1956, depicts this installation. It is believed that Pond 207-A entered service shortly after construction.

Pond 207-A is approximately 250 feet by 525 feet at the crest. When operating at its maximum allowable level, the ponds' liquid covers an area of approximately 230 feet by 505 feet. This corresponds to a surface area of approximately 116,200 square feet (about 3 acres). The maximum operating depth is approximately 7½ feet corresponding to a maximum waste volume of about 5,050,000 gallons (Rockwell International, 1988a).

Pond 207-A was redesigned in November 1963 (Figure 2-5). At this time, the asphalt planking was replaced with an approximate four-inch thickness of asphaltic concrete. The slopes of both the pond bottom and the pond sides were significantly modified. Based on these modifications, the bottom slope of the pond drained to a sump at the northeast end of the pond, and the side slopes, which had been 1:2, were changed to 1:3.7. Pond 207-A received process wastes until 1986, at which time dewatering and sludge removal operations began. Sludge was removed, thickened, and mixed with Portland cement to produce a material called pondcrete, which was then disposed off-site. As sludge was being removed from Pond 207-A, the removal of water from the pond was also conducted by natural and forced evaporation via evaporators located in Building 374. As a result of these efforts, Pond 207-A was essentially empty of materials by the summer of 1988. The last few hundred gallons of water were transferred to the 207-B ponds in order to allow the bottom to be inspected and relining operations initiated. The side slopes of Pond 207-A were relined in the Fall of 1988 to repair cracks in the side slopes as a part of the closure operations. This relining consisted of a minimum of 1/8-inch thick, rubberized, crack-sealing material, laid over the side slopes of the pond. Relining was performed to minimize potential leakage from the pond in preparation for the transfer of pumped-back ground water into the pond for evaporation. These activities were discussed with the CDH and the EPA, and proceeded as per agreements made with those agencies.

In March 1990, pumped-back ground water contained in the 207-B ponds was transferred into Pond 207-A to prevent overtopping of the 207-B ponds. Presently, Pond 207-A contains only a small volume of water and sludge which has ponded in the northeast corner of the pond. An aerial photograph taken in June 1991, Photograph 2-5, shows a southerly view of Pond 207-A and the 207-B ponds.

2.2.3 Solar Evaporation Ponds 207-B North, Center, and South

Ponds 207-B North, Center, and South were placed in service in June 1960. These ponds were also originally lined with asphalt planking (Figure 2-6). Based upon available records, it appears that the 207-B North and South Ponds were relined shortly after being placed into service. Pond 207-C liner was repaired by covering the asphalt planking with asphaltic concrete in August 1961.

Ponds 207-B North, Center, and South are each approximately 180 feet by 253 feet at the crest. When operating at their maximum allowable level, the ponds' liquids cover areas of approximately 175 feet by 245 feet. This corresponds to surface areas of approximately 42,900 square feet each (about 1 acre). Ponds 207-B North and Center have maximum operating depths of approximately 6½ feet with maximum waste volumes of approximately 1,550,000 gallons each. Pond 207-B South has a maximum operating depth of approximately 5½ feet corresponding to a maximum waste volume of about 1,400,000 gallons (Rockwell International, 1988a).

Until 1977, the three 207-B ponds had held process waste. After preliminary work was performed in 1976, the sludge from all of the 207-B ponds was removed in 1977. The liners of the 207-B Center and South ponds were also removed and disposed of off-site, and new liners were installed in these ponds. Pond 207-B South received a 45 mil thick synthetic Hypalon liner, and a leak detection system was designed for placement between the Hypalon liner and the asphalt concrete liner. The 207-B North pond contained almost no sludge and, therefore, did not have the liner removed; however, the existing liner was repaired. These activities were performed as part of the construction of the Reverse Osmosis (RO) facility and the related plant water recycle activities. Since the 1977 cleanout, the 207-B ponds have not contained process waste (Rockwell International, 1988a). These ponds have held treated sanitary effluent, treated water from the RO facility, backwash (brine) from the RO facility, and contaminated ground water pumped back to Pond 207-B North from the ITS.

Presently, the 207-B ponds are approximately filled to one-quarter to one-half capacity. They continue to receive, store and treat contaminated ground water pumped back from the ITS. An aerial photograph taken in June 1991, Photograph 2-5, shows a southerly view of the 207-B ponds and Pond 207-A.

2.2.4 Solar Evaporation Pond 207-C

Pond 207-C was placed in service in December 1970. As illustrated in Figure 2-2, Pond 207-C was constructed in the vicinity of the Original Pond. Pond 207-C has an asphaltic concrete liner system, a leak detection system, and its bottom slopes to the northeast (Figure 2-7). It is believed that Pond 207-C has not been relined since construction.

Pond 207-C is approximately 160 feet by 250 feet at the crest. When operating at its maximum allowable level, the ponds' liquid covers an area of approximately 155 feet by 245 feet. This corresponds to a surface area of approximately 38,000 square feet (about 0.9 acre). The pond has a depth of approximately 7 feet with a maximum waste volume of about 1,150,000 gallons (Rockwell International, 1988a).

Although Pond 207-C has not received process wastes since 1986, it continues to store and treat (by evaporation) these wastes. Pond 207-C is presently filled to approximately one-half capacity. An aerial photograph taken in June 1991, Photograph 2-6, shows a southerly view of Pond 207-A and Pond 207-C.

According to site personnel, the leak detection system at Pond 207-C was installed at least five years ago. The system consists of a buried length of perforated pipe connected to a sump which is located 20-30 feet north of the pond at its centerline. No flow meter was installed at the sump. No records concerning the construction of the system or any liquid volumes collected have been located. Based on observations made during its operation, the sump never collected significant amounts of liquids. The system has not been operated for about two to three years.

2.2.5 Trenches and Sumps

Operational History of Trenches and Sumps

Nitrate contamination of North Walnut Creek, located to the north of the Solar Ponds, was documented in the early 1970s. In response to this contamination, a series of trenches and sumps were installed north of the ponds during the period of 1971 to 1974. Trenches 1 and 2 were installed in October 1971, Trench 3 in September 1972, Trenches 4 and 5 in April 1974, and Trench 6 in July 1974 (Figure 2-2). Trench 5 drained by gravity to Trench 4. Water from Trench 4 was pumped to Trench 3, and Trench 3 returned the water to Pond 207-A. Water collected in Trenches 1 and 2 was pumped uphill into sumps, after which the water was returned to Ponds 207-B North and 207-A.

The locations of the sumps and trenches were established based upon evidence of nitrate-impacted vegetation. The water present in these areas was sampled, and if the presence of nitrate contamination was confirmed, a trench was typically installed. These trenches and sumps intercepted natural seepage and pond leakage that might otherwise have entered North Walnut Creek, and were successful in reducing nitrate levels in North Walnut Creek (ASI, 1991).

In addition to the trenches and sumps described above, an additional control structure was built to transfer water to Pond 207-A. This structure consisted of a pump-well with a submersible pump located in the area in which footing drain flows from Buildings 771 and 774 could be collected. The purpose of the system was to better manage contaminated water. The footing drain flows both surface in the general location of the small pond due east of the currently unused condensate tanks that are north of Building 774. The pump would remove water from the area in which the footing drains surface and pump the water to Pond 207-C. It is believed that this system was constructed in approximately 1975. This structure is sometimes referred to as the West Collector (ASI, 1991).

The trenches and sumps were in operation until the early 1980s when they were replaced by a more extensive french drain system (the ITS). The trenches and sumps that were not destroyed in construction related to the PSZ were abandoned in-place by cutting their electrical power supply.

2.2.6 Interceptor Trench System

The Interceptor Trench System (ITS), also known as the French Drain System, was installed as a part of the construction of the Perimeter Security Zone (PSZ) at the Rocky Flats Plant. This ground water and seepage collection system was designed and constructed to minimize the seepage of waters into North Walnut Creek. The depths of the french drains range from approximately 1 to 27 feet below the ground surface, with typical depths of 4 to 16 feet (Rockwell International, 1988a). The gravel-filled trenches of the french drains are approximately one foot wide, with perforated pipe in the bottom to intercept and transport flow to the Interceptor Trench Pump House (ITPH). A cross section through most of the ITS is similar to the cross section presented in Figure 2-8 for the trenches.

A portion of the ITS was designed to collect surface runoff in addition to ground water and seepage. French drains in this portion were filled with gravel to the ground surface rather than capped with backfill. This portion of the system is present immediately north of the Solar Ponds and is identified in Figure 2-2 as segment D-D'.

One portion of the ITS was extended to the west to collect flow from Buildings 771 and 774 footing drains. The portion of the ITS collecting this flow is identified on Figure 2-2 as segment E-E'.

Ground water collected in the ITS flows by gravity to the ITPH. The liquid from the pump house is then pumped to Pond 207-B North. The current amount of ground water and seepage collected by the ITS is estimated to be approximately 4 million gallons per year. The maximum amount of water collected in any one week was 700,000 gallons in June 1987 (Rockwell International, 1988a).

2.3 PREVIOUS INVESTIGATIONS

A number of previous investigations have been conducted at site for the purpose of evaluating physical characteristics, including surface water and ground water flow and quality. Previous studies that were the primary sources of information for this Work Plan include:

- ASI; Solar Ponds Interceptor Trench System Ground Water Management Study, Rocky Flats Plant Site, Task 7 of the Zero-Off-site Water-Discharge Study; January 15, 1991

- Dames & Moore; Summary of R.F. Weston's Sampling and Analysis of Solar Pond Water and Sludge Report; Rocky Flats Plant, Golden, Colorado; September 18, 1991

- EG&G Rocky Flats, Inc.; Draft Final Geologic Characterization Report for RFP; July 1991

- EG&G, Draft Well Abandonment and Replacement Program Work Plan for Rocky Flats Plant; June 1991

- EG&G Rocky Flats, Inc.; 1990 Annual RCRA Ground Water Monitoring Report for Regulated Units at Rocky Flats Plant Volume I; March 1, 1991

- EG&G Rocky Flats, Inc.; Final Background Geochemical Characterization Report: Rocky Flats Plant for 1989; December 1990

- 1989 Soil Boring Program summarized in the EG&G RFEDs (database)

- Hydro-Search, Inc.; Hydrogeologic Characterization of the Rocky Flats Plant, Golden, Colorado; Project Number 1520; 55 p.; December 9, 1985

- Rockwell International; Closure Plan: Solar Evaporation Ponds; U.S. Department of Energy; Rocky Flats Plant, Golden, Colorado; Volumes I through IV; Unnumbered Report; 1988

- Roy F. Weston, Inc.; Sampling and Analysis of Solar Pond Water and Sludge; EG&G Rocky Flats, Inc.; Rocky Flats Plant, Golden, Colorado; July 19, 1991

- U.S. DOE, Draft Phase I RFI/RI Work Plan for the Solar Evaporation Ponds (OU4); Rocky Flats Plant, Golden, Colorado; June 1990.

The following is a brief description of some of the investigations which have been conducted in and around OU4. Some of the earlier investigations have not been referenced extensively in this Work Plan and hence do not appear in the list above.

In 1970, Woodward-Clyde and Associates conducted an investigation of a potential landslide area north of the Solar Ponds. Test holes were drilled to assist in the determination of subsoil and ground water conditions and evaluate landslide risk. Ten test holes were drilled, and up to 6 feet of fill was encountered, underlain by 5 to 21 feet of clay, clayey gravel and sand, and weathered claystone. Also, free water was encountered in all test holes. The study concluded that the hillside below the ponds is a high risk area for landsliding, particularly with the probable addition of subsurface water flows from the ponds. In addition, it was recommended that a drainage system to remove subsurface water be installed (Woodward-Clyde & Associates, 1970).

Engineering Science, Inc. (1975) conducted an investigation concerning the problem of nitrate salts being transported from the Solar Ponds area into North Walnut Creek. Ten holes were drilled along the north and east exterior of the Solar Ponds and 21 additional test holes were drilled down the north slope of the ponds to determine the distribution of contaminated soil. These holes were terminated in bedrock and samples were collected for laboratory analysis. Findings from this study indicated that soils north and east of the Solar Ponds were contaminated with nitrate and that these nitrates would continue to be leached from the contaminated soil and be transported to North Walnut Creek (Engineering Science, 1975).

Another geotechnical investigation was conducted in 1984 by Geotechnical and Materials. Two exploratory test borings were drilled southeast and east of Pond 207-C to describe the subsurface conditions and recommend suitable types and depths of foundations for proposed new structures. These borings terminated approximately 14 feet below the existing grade in overburden materials. This study concluded that the proposed structures could be founded on spread footings, ring-wall, or mat foundations bearing on the in situ soils (Geotechnical and Materials Consultants, 1984).

Hydro-Search, Inc. (1985) presented a site-wide hydrogeologic characterization of the RFP. This report describes the hydrogeologic and ground water quality conditions based on existing data at the time. The existing ground water monitoring system was described and evaluated, and recommendations were made for a new monitoring program (Hydro-Search, 1985).

In 1986, R. L. Henry (Rockwell International) submitted a report summarizing trends observed in the surface water monitoring at the RFP. The report discusses the surface water control system (SWCS) completed in 1980, which is designed to divert flow around the RFP and collect surface runoff and store it temporarily for monitoring before discharge. Nonradioactive and radioactive trends in the surface water were also discussed (Henry, R.L., 1986).

In 1986, Chen and Associates prepared a closure plan for the Solar Ponds. The plan describes the construction and operation procedures at the Solar Ponds including past use, size and volume of impoundments, waste inventory, and treatment and disposal of wastes. This closure plan was revised in 1987 and again in 1988 (Rockwell International, 1988a).

Twenty-one ground water monitoring wells were installed in 1986. These wells were installed to characterize the hydrogeology in the Solar Ponds area and to evaluate if the Solar Ponds were an imminent threat to the public or the environment.

Chen and Associates prepared a preliminary prioritization of sites at the RFP. The prioritization of sites was based on review of previous investigations and historical aerial photographs. The Solar Ponds were considered a priority site (U.S. DOE, 1986a).

In 1987, six monitor wells and 14 boreholes were drilled for characterization of the Solar Ponds area. Results of this drilling program are presented in Volume II of the 1988 Closure Plan (Rockwell International, 1988a).

In 1989, 32 monitoring wells were installed in the Solar Ponds area by Rockwell International. During the drilling, soil samples were collected for chemical and/or radiological analysis. Water levels and the results of ground water sample analysis from these wells are reported in 1989 Annual RCRA Ground Water Monitoring Report for Regulated Units at Rocky Flats Plant (EG&G, 1990a). Soil sample analytical results are in the RFEDs database and general conclusions of the results discussed in this Work Plan. No report is available summarizing the 1989 soil sampling program at the Solar Ponds, however, analytical results are included in Appendix E.

2.4 SITE GEOLOGY AND HYDROLOGY

2.4.1 Site Geology

Numerous investigations have focused on the geology of the RFP including extensive drilling in the Solar Ponds area. The following discussion of site geology has taken into consideration the results of the Solar Evaporation Ponds Closure Plan (Rockwell International, 1988a), the 1989 drilling program performed by Weston, EG&G Rocky Flats Summary of Field Investigations and EG&G Rocky Flats Draft Final Geologic Characterization Report (EG&G, 1991i).

Figure 2-9 shows the locations of monitoring wells and soil borings utilized in preparation of this Work Plan. The locations of boreholes, data for which were also used, are shown in Figure 2-23. Figure 2-9 also shows the locations for cross sections A through D presented in Figures 2-10, 2-11, 2-12, and 2-13. Cross sections A through D show the bedrock elevation and alluvial thickness. Figure 2-14 illustrates the bedrock geology. Original borehole lithology and construction logs are contained in Appendix B. Many of the logs were revised as a result of re-logging the cores, during 1989 and 1990. The revised borehole data have been summarized for all RFP areas in the Draft Final Geologic Characterization Report (EG&G, 1991i). A separate spreadsheet containing only the borehole data pertaining to the Solar Ponds area was developed as a subset of the spreadsheet summary for all RFP data. This spreadsheet is also contained in Appendix B, and has been relied upon for the development of the cross sections and bedrock map. Total depth of the 78 borings ranges from 7 to 157 feet, and averages 34 feet.

Geologic interpretations presented in the maps and cross sections are based primarily on the borehole spreadsheet data contained in Appendix B, which represent the most consistent and accurate data available to work with. However, because the spreadsheet data account for only sandstone lithologies below the surface of the bedrock, original logs were utilized to delineate non-sandstone lithologies below the bedrock surface on the cross sections. Many of the original borehole logs disagree with the spreadsheet data, as a result of the re-logging activities discussed above. The cross sections show all unconsolidated materials grouped into a single unit referred to as Rocky Flats Alluvium. This includes the Rocky Flats Alluvium, which is predominantly a gravel and caps the erosional highs, as well as the Colluvium and Valley Fill which are predominantly clays. These units are discussed separately below. The cross sections contain additional data pertaining to well completion and water levels. The well completion data are summarized in Table 2.4 and the water level data are taken from the 1990 Annual RCRA Ground Water Monitoring Report (EG&G, 1991d).

The cross sections and the bedrock geology map show the presence of a partially developed Arapahoe Sandstone channel system, grading from claystone boundaries to silty claystones, siltstones, and sandstone lenses within the channel. The sandstones are best developed at the bedrock surface underneath Pond 207-C and to the southeast of the 207-B ponds along South Walnut Creek. The 1988 Closure Plan identified a sandstone lens at the southeast corner of Pond 207-A, based on a sandstone described at the bedrock surface in borehole SP 04-87. Re-logging efforts have since determined only the presence of claystone as is indicated in the borehole spreadsheet data, and is shown on the Bedrock Geology Map. A smaller sandstone subcrops to the north of Pond 207-A in North Walnut Creek. This sandstone was encountered with borehole SP 11-87. East-west cross sections B-B', C-C', and D-D' show the presence of lower sandstone units, extensive silty claystones and siltstones at the south end of the area, and subcropping sandstones becoming more dominant to the north. Bedrock becomes more shallow in the north end of the area. Lower sandstone units in cross sections B-B' and D-D' were not encountered in any of the shallow borings in C-C', but are likely to be present. No attempt was made to correlate or project the presence of the sandstones in the cross sections. Cross section A-A' (looking west) suggests the presence of a channel system. The more erosion resistant sandstones and silty claystones in this area have formed an erosional high.

2.4.1.1 Surface Geology

The Solar Ponds are located on a Pre-Wisconsin pediment remnant, referred to as part of the Plant Interfluve. The pediment is capped by the Rocky Flats Alluvium. Cross sections A through D illustrate the bedrock elevation and the overlying unconsolidated materials. The pediment erosional surface was cut by west-to-east flowing streams, which are believed to have had as much as 30 feet of cross-section relief. Later erosion was possibly controlled by Pre-Wisconsin topography, ultimately breaching the alluvial cover, exposing bedrock units and following the earlier defined drainage systems.

The Quaternary deposits of the RFP area are described in Section 1.3.3.7. The Rocky Flats Alluvium is the only Quaternary deposit underlying the Solar Ponds area. Other more recent unconsolidated deposits have been identified at the Solar Ponds area and are discussed in detail below (Rockwell International, 1988a). Most of the Solar Ponds area has been disturbed by construction of the ponds and the ITS, as well as nearby buildings and other infrastructure. Rocky Flats Alluvium often occurs below the limits of the disturbed ground, according to borehole logs. All unconsolidated units have been grouped together as Rocky Flats Alluvium in the cross sections, for ease of illustration. Thickness of the entire unconsolidated interval ranges from 0 to 27 feet, with an average of 10 feet.

Rocky Flats Alluvium

The Rocky Flats alluvium occurs on top of the erosional bedrock highs in the Solar Ponds area and is generally poorly sorted containing a range of clay, silt, sand, and gravel deposits. Colors vary from light brown to gray brown, dark yellowish-orange, grayish-orange, and dark gray. The material is mildly calcareous and weakly cemented in areas. It also contains occasional boulders and re-worked bedrock materials, which can cause problems in distinguishing the true bedrock surface during drilling.

Colluvium

Colluvium occurs on the hill slopes northeast and southeast of the Solar Ponds descending to North and South Walnut Creeks. It consists of unconsolidated clay with silty clay, sandy clay, and gravel layers. Colors vary from dark yellowish-brown to light olive gray and light olive brown. Occasional dark yellowish-orange iron staining is present. Occasional cobbles occur in the gravel layers.

Valley Fill Alluvium

Valley fill alluvium occurs in the drainages of North and South Walnut Creek and consist of unconsolidated, poorly sorted sand, gravel, and pebbles in a silty clay matrix. Colors range from olive gray to dark yellowish-orange to dark yellowish-brown.

Disturbed Ground

Disturbed ground overlies the Rocky Flats Alluvium in the ponds area, and the colluvium on the hill slopes in the ITS area. Disturbed ground consists of unconsolidated clay, silt, sand, gravel, and pebbles. Colors range from olive to reddish brown to yellow gray and yellow orange.

Artificial Fill

Artificial fill occurs in close proximity of the ponds and contains materials that have obviously been transferred from other locations. The fill consists of sandy clay and gravels. Materials are poorly sorted with fragments of claystone and concrete rubble. Colors range from pale to dark yellowish-brown.

2.4.1.2 Bedrock Geology

The Cretaceous Arapahoe Formation unconformably underlies the unconsolidated deposits in the Solar Ponds area. The Arapahoe Formation primarily consists of claystones and silty claystones. A subcropping sandstone has been mapped in the vicinity of Pond 207-C and along South Walnut Creek. A discussion of the depositional environment for the Arapahoe Formation may be found in Section 1.3.3.7 Regional Geology, in the sub-section entitled Upper Cretaceous Deposits. Figure

2-14 shows the bedrock geology. Figures 2-10 through 2-13 show the cross sections A through D, locations for which are shown in Figure 2-9.

The Bedrock Geology map shows three mappable units, one of which consists predominantly of sandstones, another of which consists predominantly of silty claystones and siltstones, and the last of which consists predominantly of claystones. The silty claystone unit is referred as such to coincide with the borehole spreadsheet bedrock lithology data in Appendix B. This mappable unit also includes all clayey siltstones and siltstones indicated below bedrock surface on original lithology logs. Siltstones are also likely to exist at bedrock surface inbetween borehole locations, interlayered with the silty claystones. All three mappable units are transitional and gradational and are distinguished only for the purpose of developing a conceptual understanding of the predominant bedrock lithologies. All delineations shown are subject to major revision, pending the results of the field investigation.

Arapahoe Sandstones

Sandstones in the Arapahoe Formation are poorly to moderately sorted, subangular to subrounded, clayey, silty, very fine-to medium-grained, with occasional occurrences of coarse-to conglomeratic. Trough and planar cross stratification are common sedimentary structures (EG&G, 1991i). Sandstones are lenticular in geometry and are interlayered with thin lenses of clay and silt.

The subcropping sandstones dip approximately 1.5 degrees to the east and are generally weathered within 30 to 40 feet of the base of the alluvium. The weathered section colors vary from pale orange to yellowish-gray and dark yellowish-orange. Unweathered sandstones are light to olive gray. Fractures have been noted in the weathered zone at depths of 5 feet to 14 feet.

A total of four sandstone intervals have been identified in the Arapahoe Formation in the Solar Ponds area, although some uncertainty exists as to whether the lower sand intervals occur as Arapahoe or Laramie sandstones. The Arapahoe Sandstone No. 1 unit outcrops and subcrops in the Solar Pond area. Data contained in the borehole spreadsheet in Appendix B are summarized below for all sandstone intervals:

Sandstone Interval	Elevation (feet)	Thickness (feet)	Percent >200/230 Sieve Size (average)
1	5,946 - 5,973	12 - 29	47
2	5,928 - 5,883	4 - 13	28
3	5,872 - 5,854	5 - 8	4
4	5,868 - 5,803	2 - 13	35

As defined, the sandstone intervals contain abundant lenses of interlayered claystones and siltstones, keeping the actual percentage of sand relatively low.

Arapahoe Claystones/Silty Claystones

The Arapahoe claystones and silty claystones are massive and blocky, containing thin laminae and stringers of sands, silt, and lignite. The weathered zone in this material extends from 28 to 39 feet below the base of the alluvium. Weathered claystones range in color from pale yellowish brown to light olive gray and are moderately stained with iron oxides. Unweathered claystones are typically dark gray to yellowish gray.

Fractures have been encountered between 6 and 26 feet in depth, and are associated with ironstone concretions and calcareous deposits in the weathered zone. Vertical, subvertical, horizontal, and 45 degree fractures have been encountered in the unweathered zone at depths of 30 feet to over 100 feet. Many of the shallower fractures are stained with iron oxides or calcareous deposits, implying water movement (Rockwell International, 1988a).

Laramie Formation

The upper contact of the Laramie Formation is believed to occur at a depth of approximately 260 feet in the Solar Ponds area, although none of the boreholes drilled to date are believed to have encountered the Laramie (EG&G, 1991i, Geologic Cross-section G-G′). The estimated elevation for the contact is based on a correlation of the Laramie/Arapahoe contact established through the surficial geologic mapping effort to a nearby borehole (B304289) at a depth of 30 feet (EG&G, 1991i). The Upper Laramie, which consists mostly of silty claystones, siltstones, and some fine-grained sandstones, is estimated to be 460 feet thick at borehole B304289. The lower unit of the Laramie Formation consists of coal beds and sandstones and is estimated to be 285 feet in thickness, based on correlations from earlier work by Wiemer.

Geologic Cross-sections

Geologic cross-section A-A' (Figure 2-10) trends south to north through the solar ponds area from well No. 3386 to well No. B208789 near North Walnut Creek. Topography is relatively flat in the Solar Ponds area except where artificial dikes have been built. Ground surface slopes steeply from an area north of the ponds through the protected zone and ITS towards North Walnut Creek. Quaternary alluvial thickness is approximately 10 feet in the pond area. The Arapahoe silty claystone subcrops throughout the section, except for a small lense of sandstone between ponds 207-A and 207-B South. Arapahoe claystones exist at both ends of the cross section.

Geologic cross-section B-B' (Figure 2-11) trends west to east south of the Solar Ponds area from well No. 2386 near Building 779 to well No. B213789 near South Walnut Creek. Quaternary alluvium thickens from five feet in the west to 10 feet east of the Solar Ponds area, then thins again down the slope towards South Walnut Creek. Arapahoe claystone subcrops in the west, and Arapahoe silty claystone subcrops in the area of Pond 207-A and Pond 207-B South. Sandstone No. 1 subcrops in the east near South Walnut Creek.

Geologic cross-section C-C' (Figure 2-12) trends west to east, south of Pond 207-C and through Pond 207-A and 207-B and continues south from well No. P209389 near Building 774 to well No. 2986 west of the perimeter security zone. Quaternary alluvium ranges in thickness from 7 to 15 feet. Top of the bedrock in the vicinity of Pond 207-C is the Arapahoe Sandstone No. 1. The sandstone is lenticular in shape with a maximum thickness of 22 feet and thins to 7 feet towards the east. The Arapahoe silty claystone is the top of bedrock beneath ponds 207-A and 207-B south. A gradational facies change from silty claystone to claystone occurs between wells 210289 and 207989. Changes in bedrock geology at depth can not be determined along this cross-section because all wells are shallower than 38 feet.

Geologic cross-section D-D' (Figure 2-13) trends west to east north of the solar ponds from well No. P219189 located near Building 774 to well No. B208189 to the east. Topography is hummocky along this cross section, rising northwest of Pond 207-C and then sloping downward towards the east. Quaternary alluvium is approximately 10 feet thick in the west until it pinches out at the Arapahoe Sandstone No. 1 bedrock outcrop located north of Pond 207-A. The thin veneer of alluvium stretches eastward, where it thickens to 12 feet in the valley. The bedrock Arapahoe formation grades rapidly through facies changes from west to east. In general, the Arapahoe Sandstone No. 1 is lenticular in shape and outcrops in the vicinity of pond 207-C with a thickness of 30 feet, and thins easterly to 15 feet. Arapahoe Sandstone No. 2, 3, and 4 were encountered at depth. Additional information is needed to determine if these sandstones are laterally continuous. A large deposit of silty claystone is continuous eastward from well P209889 and gradationally changes to claystone.

Geomorphology

The land surface of the Solar Ponds area consists of an alluvial-covered pediment which has been deeply incised with east-trending streams. The streams have dissected both the alluvium and the underlying bedrock units along the drainages. It is conceivable that all sandstone intervals of the Arapahoe Formation have been exposed surficially within the corresponding elevations and locations along the drainages.

The extent to which exposed bedrock units can provide pathways to underlying strata is not fully known. However, outcropping and subcropping sandstones of the Arapahoe Formation are extensively interlayered with claystone and siltstone lenses, which serve as relatively impermeable barriers to downward migration of contaminants. The sandstones and claystones are lenticular and are likely to be laterally discontinuous.

2.4.2 Hydrology

2.4.2.1 Ground Water

Numerous investigations have focused on the geology and hydrogeology of the RFP including extensive drilling in the Solar Ponds area. The following discussion of site hydrogeology has taken into consideration the contents of the Solar Evaporation Pond Closure Plan (Rockwell International, 1988a), the results of the 1989 drilling program (performed by R.F. Weston), the Rocky Flats Summary of Field Investigations, the Rocky Flats Draft Final Geologic Characterization Report (EG&G, 1991i) and the Draft Phase I RFI/RI Work Plan for the Solar Evaporation Ponds (U.S. DOE, 1990b). Wells located within the Solar Ponds area are illustrated in Figure 2-15. Hydrologic data is included in Appendix C. Well completion records and borehole logs for the 1989 drilling program are included in Appendix B, all other records can be found in the Solar Evaporation Pond Closure Plan (Rockwell International 1988a).

Generally, ground water in the Solar Ponds area flows east. Flow in the unconsolidated material generally follows the contact with the Arapahoe Formation claystones. The claystones have a low hydraulic conductivity, on the order of 1×10^{-7} centimeters per second (cm/s), effectively constraining much of the flow within the uppermost hydrostratigraphic unit above the alluvial/bedrock unconformity (Table 2.1). The exception to this is the occurrence of ground water in the subcropping units beneath the alluvial material. In this situation, the ground water exists under unconfined conditions within the bedrock. In the Solar Ponds area, Arapahoe No. 1 Sandstone subcrops beneath Ponds 207-C and the northwest portion of Pond 207-A. The confining layers for the sandstones are the claystones and silty claystones of the Arapahoe Formation. The hydraulic conductivity of the Rocky Flats Alluvium and the Arapahoe No. 1 Sandstone is approximately 6×10^{-5} cm/s. The lower Arapahoe sandstones have a hydraulic conductivity of approximately 10^{-6} cm/s (Table 2.1).

Ground water flow in the Solar Ponds area is influenced by (1) recharge of precipitation, (2) leakage from the Solar Ponds and (3) drainage into the ITS. The amount of pumpage from the ITS is estimated at 4 million gallons per year. North of the Solar Ponds, the ITS drains ground water from the alluvial materials creating an area of unsaturation (Figure 2-16).

Upper Hydrostratigraphic Unit

In the upper hydrostratigraphic unit, the unconfined ground water table forms a smooth continuous surface sloping away from Pond 207-C through both the alluvial unit and the Arapahoe No. 1 Sandstone (Figure 2-12). In the vicinity of Pond 207-C, ground water flow appears to be in a westerly direction.

The potentiometric surface in surficial materials for first and third quarters 1990 are presented in Figures 2-16 and 2-17 for the Solar Ponds area. The first and third quarters represent the seasonal high and low flows, respectively. Ground water elevations for first and third quarters 1990 are presented in Tables 2.2 and 2.3. Well construction details are included in Table 2.4. Depth to water in alluvial materials ranges from 4 to 12 feet. Alluvial ground water enters the Solar Ponds area from the west and flows easterly (EG&G, 1991d).

Hydrographs were constructed for alluvial wells No. 3086, 2886, and 2686, located north of ponds 207-A and 207-B North, east of Pond 207-B North and south of 207-A, respectively. These wells show a similar trend in water level fluctuations with highs occurring in the summer months of May through August 1990 and 1991 and lows occurring in the winter months of November through February 1990 and 1991 (Figure 2-18).

Lower Hydrostratigraphic (Confined) Unit

Ground water flow within weathered bedrock is similar to that in surficial materials. First and third quarter potentiometric surface maps (Figures 2-19 and 2-20) show ground water flowing in an easterly direction. Water levels taken during 1990 indicate that the first and third quarters represent the seasonal high and low flows for the area (Tables 2.5 and 2.6). An area of unsaturated bedrock exists north of the Solar Ponds area, but is not extensive enough to prevent flow into North Walnut Creek (EG&G, 1991d). The hydraulic conductivity of the lower HSU (Arapahoe Claystone weathered and unweathered) ranges from 5.4 x 10^{-7} to 4 x 10^{-8} cm/s (Table 2.1).

Hydrographs were constructed for bedrock wells 2786 and P208889 (Figure 2-21). These graphs show that water levels fluctuated as much as 20 feet in well no. P208889 and 60 feet in well no. 2786. The cause of these water fluctuations is unclear, but may be due to poor well construction and/or inaccurate field measurements.

2.4.2.2 Surface Water

Surface water flow from the Solar Ponds area is toward North Walnut and South Walnut Creeks. A series of retention ponds known as the A-series ponds are located on North Walnut Creek, and a series of retention ponds known as the B-series ponds are located on South Walnut Creek (Figure 2-22). South Walnut Creek joins North Walnut Creek and an unnamed tributary coming from the landfill area, approximately 0.7 mile downstream of the eastern edge of the Plant security area, within the buffer zone. Walnut Creek then flows eastward approximately 1 mile into Great Western Reservoir.

North Walnut Creek

North Walnut Creek is an eastward flowing stream located north of the Solar Ponds area. Surface runoff patterns follow surface topography and indicate flow entering the drainage from the Solar Ponds area, the 700 Building Complex, the 300 Building Complex, and general surface runoff from the north and west sides of the Plant (Rockwell International, 1988a). Due to the surface drainage pattern, any releases from the 700 and 300 areas would flow into North Walnut Creek above the retention ponds in the drainage area located north of Pond 207-C (Rockwell International, 1988a).

The A-series ponds on North Walnut Creek are designated A-1, A-2, A-3, and A-4, from west to east. Currently, Ponds A-1 and A-2 are used only for spill control, and North Walnut Creek stream flow is diverted around them through an underground pipe. Previously (until 1980), Ponds A-1 and

A-2 were used for storage and evaporation of laundry water. Pond A-3 receives the North Walnut Creek stream flow and runoff from the northern portion of the Plant. Pond A-4 is designed for surface water control and for additional storage capacity for overflow from Pond A-3.

South Walnut Creek

South Walnut Creek is an eastward flowing stream located to the east of the Solar Ponds area. South Walnut Creek receives surface water runoff from the central portion of the Plant site. The Plant surface water drainage pattern indicates surface water drainage from the area south and southeast of the 207-B ponds flowing in a southeasterly direction toward South Walnut Creek. However, the drainage pattern also indicates runoff from the Mound and 903 Pad areas located to the south of the Solar Ponds would contribute to flow in South Walnut Creek (Rockwell International, 1988a).

The discussion of the 903 Pad, Mound, and East Trenches Areas Remedial Investigation Report attributes most of the surface water contamination in South Walnut Creek to the Mound and 903 Pad areas. For this reason, it is not felt that the Solar Ponds are contributing to South Walnut Creek contamination (Rockwell International, 1988a).

2.5 NATURE OF CONTAMINATION

A discussion of the nature of contaminants in the sources and affected media at the Solar Ponds is presented in this section. The primary emphasis is placed on characterizing both the current and historical composition of the pond liquids and sludges, and on characterizing the nature of contaminants in unsaturated soils near the site. Overall contamination at the Solar Ponds is characterized by assessing the distribution of compounds common to the sources, soil, ground water, surface water and air. Results from the multiple sampling efforts conducted on each of the sources and other media have been informally summarized and discussed in following subsections to enable an initial understanding of the type of contamination present in the Solar Ponds and media interactions occurring at the site.

As a result of this preliminary data review, it was found that the ponds are sources of nitrate, metals and radionuclides to underlying soils and ground water, and to surface water. Organic compounds were detected only infrequently in all media, and at low concentration, indicating organic compounds are of only minor significance to the overall characterization. Pond liquid and sludge contained elevated concentrations of metals and inorganics that are relatively immobile without the presence of water to provide a transport mechanism. The ponds were high in nitrate, however, which was observed in all other media (except air) in a pattern indicating migration northward to the ITS and North Walnut Creek. Radionuclides were distributed in much the same pattern, although surface radiological studies indicate Pond 207-A to be a relatively unique source of surficial plutonium and americium. Other compounds showing a distribution pattern in soils are cyanide, chromium and lithium. Radionuclides present in pond liquid and sludge including americium-241, plutonium-239 and tritium are also evident in soils surrounding the Solar Ponds.

2.5.1 Sources -- Solar Evaporation Ponds

Wastes present in the five Solar Ponds differ based on their varied influent waste streams and their recent histories. Although all ponds have received facility process wastes in the past, recent maintenance, closure, and aquifer restoration activities have resulted in dissimilar waste characteristics in: Pond 207-A; Ponds 207-B North, 207-B Center, and 207-B South; and in Pond 207-C. Process waste water and sludge were removed from Pond 207-A as a part of closure activities in 1988, and the pond currently holds pumpback water from the ITS and incident precipitation. The process waste contents of Ponds 207-B North, Center, and South were removed during maintenance activities and the liners replaced in 1977. The linings of Ponds 207-B Center and 207-B South were removed, bagged, cemented and disposed of off-site. These ponds currently collect contaminated ground water from the ITS and Building 771 and 774 footing drains. The 207-B ponds were also used for storage and treatment by evaporation of sanitary effluent and treated water and backwash brine from the RO facility. Pond 207-C is the only pond that currently contains plant process wastes. In addition to these five active ponds, the Original Pond ceased to be used after 1956, and was filled and regraded in 1970. Contamination from this Original Pond may be present in soil beneath and surrounding Pond 207-C. As evidenced in aerial photographs, soil from the Original (clay-lined) Pond were possibly used in the construction of Pond 207-C (Rockwell International, 1988a).

To characterize waste composition in the Solar Ponds, numerous analyses of pond liquids and sludge have been conducted. Summaries of the laboratory results for pond liquids and sludges are presented in Tables 2.7 through 2.11 and supporting documentation provided in Appendix D. These tables contain a range of historical concentrations from the 1984-1988 time period, as well as recent sampling results from 1991. Although the historical results provide an indication of past waste characteristics, the 1991 data are considered more reliable as an indicator of current waste composition. Detailed laboratory data for the 1984-1988 time period are presented in Appendices 3 and 4 of the 1988 Solar Evaporation Ponds Closure Plan (Rockwell International, 1988a) while recent 1991 sampling results are presented in the Dames & Moore Summary Report (Dames & Moore, 1991). Visual descriptions of sludges were obtained from the Sampling and Analysis of Solar Pond Water and Sludge Final Report (Weston, Roy F., 1991).

2.5.1.1 Pond 207-A

A comparison of historical 1984-1988 and recent 1991 liquid and sludge sampling results for Pond 207-A reflects the removal of wastes from this pond in 1988 (Table 2.7). Historical results are similar to the characterization of Pond 207-C liquids and sludges, although the radionuclides and beryllium occurred at higher concentrations in Pond 207-A prior to waste removal. Acetone and tetrachloroethylene were detected in historical analyses of Pond 207-A sludge, but these common solvents were also detected in associated field blanks. Fluoranthene, di-n-butylphthalate and bis-(2-ethylhexyl)phthalate were also detected in Pond 207-A sludge during removal. Fluoranthene is a polynuclear aromatic hydrocarbon, and may be derived from the asphalt liner. The phthalate compounds are plasticizers. Pond 207-A currently collects only incident precipitation, although it has also been used to store ground water from the collection system. Concentrations of radionuclides, including americium, plutonium, uranium, and tritium, were greatly reduced after wastes were removed. Other characteristic waste stream constituents, such as nitrate and the alkali metals sodium and potassium, have decreased in concentration by several orders of magnitude since removal of pond liquids and sludge. In addition, other transition metals, such as chromium and nickel, are currently undetectable. Total cyanide occurs at relatively high concentrations, and high total dissolved solids content reflects the evaporative concentration of minor influent salts within the pond, as well as possible dissolution of remaining trace salts following waste removal. Chemical sludges, which historically contained high concentrations of radionuclides, transition metals, and salts, are no longer evident in Pond 207-A. Recent descriptions of the minor amount of solids present indicate that they are composed of primarily sediments and algae. As a result, sludges were not collected for analysis during the 1991 sampling effort.

Pond 207-A was originally designed in 1956 with ½-inch asphalt planking which was removed in 1963 and replaced with an asphaltic concrete liner. A sump is located in the northeast portion of the pond and the pond slopes toward the sump. No contaminant or leakage rate information is available on the pond. There was documented evidence in 1988 of pond liner leakage on the side slopes. The side slopes were relined in 1988 with an 1/8-inch thick rubberized crack sealing material to minimize pond leakage. A surface water seep is observed near the northeast corner of the pond and is most likely a result of liner leakage in this vicinity.

2.5.1.2 Ponds 207-B North, Center, and South

Ponds 207-B North, Center, and South currently receive contaminated ground water from the ITS and from Building 771 and 774 footing drains. Pumped-back ground water is introduced into Pond 207-B North, and is subsequently transferred into Ponds 207-B Center and South. As a result of the storage and evaporation of ground water rather than waste water, the composition of Pond 207-B North, Center, and South liquid and sludge differs considerably from the contents of Ponds 207-A and 207-C. As shown in Tables 2.8, 2.9, and 2.10, Ponds 207-B North, Center, and South liquids contain nitrate as the dominant anion followed in abundance by chloride and sulfate. The dominant cations are the alkali metals sodium and potassium, while alkaline earth metals calcium and magnesium occur in lesser concentrations. The presence of calcium and magnesium in these pond liquids reflects the occurrence of these alkaline earth metals in local ground water. Radionuclide concentrations in the 207-B ponds are intermediate between the characteristics of Pond 207-A liquid, which is derived primarily from ground water pump-back and incident precipitation, and Pond 207-C liquid, which is representative of process wastewater. Transition metals characteristic of the process wastewater including cadmium, copper, chromium, and nickel, are absent or present only at relatively low concentrations in 207-B pond liquids. Historical analyses indicate the presence of methylene chloride in Pond 207-B North liquid, although this compound was also detected in field and laboratory blanks.

Visual descriptions of sludge from Ponds 207-B North, Center, and South indicate brown to green algae as the primary constituent. Analytical results indicate the presence of calcium and sodium salts of nitrate, chloride, and sulfate. Fluoride is absent. Radionuclides are present at relatively low levels, with the exception of uranium-234 and uranium-238 isotopes. These two naturally occurring uranium isotopes occur in 207-B pond sludges at concentrations intermediate between Pond 207-C sludge and the former 207-A sludge. These uranium isotopes may be derived from process wastes which have reached ground water, or may be naturally elevated in local ground water. Transition metals representative of process wastes, including chromium and copper, are present in Pond 207-B sludges, although cadmium and nickel are absent. A variety of semivolatile organic compounds were detected in the Pond 207-B North sludge composite sample. None of these compounds were verified as present in the individual samples comprising the composite, however.

The liners originally installed in 1960 for Pond 207-B North, Center and South consisted of asphalt planking. In 1960 and 1961, the asphalt planking was covered with asphaltic concrete. In 1977, the 207-B Center and South were removed, bagged, cemented and disposed of off-site. The 207-B North pond liner was not removed. The 207-B South pond received a 45 mil synthetic geomembrane and a leak detection system was installed. An underdrain system was reportedly installed on all three 207-B ponds, which was designed to collect ground water flow under the ponds and route it north along the ponds eastern edges, then discharge it to an open ditch north of Pond 207-B North. It is unknown if the underdrain system was installed.

No information regarding contaminants below the liner or estimated leakage flow rates are available on the 207-B Ponds. If the underdrain systems exist, they may collect ground water and leaking pond liquids and transport them via closed conduit to ditches north of the ponds. With the ITS in place and correctly operating, discharge to this ditch should be collected either as surface water in the gravel trench system or as ground water that has reinfiltrated below the surface.

2.5.1.3 Pond 207-C

The liquid and sludge contained within Pond 207-C is derived from the plant process waste water stream. Historical concentrations measured during the 1984-88 time period are consistent with recent 1991 sampling results, as summarized in Table 2.11. Recent results generally occur with the range of historical concentrations, where comparable data are available. Pond liquid characteristics include high nitrate and cyanide concentrations, although chloride, carbonate and sulfate predominate as major anions in solution. The alkali metals potassium and sodium occur as the dominant cations in solution. Total dissolved solids contents are approximately 40 percent, and have increased between the 1984-88 and 1991 time periods, consistent with the continued influx and evaporation of plant process wastes. Solution pH is alkaline, and the presence of sulfide suggests the possibility of reducing conditions. Radionuclides, including americium, plutonium, uranium, and tritium, are present within the pond liquids. Cadmium, chromium, copper, and nickel occur as the primary transition metals. The occurrence of radionuclides and transition metals as primarily dissolved constituents within the pond liquids is suspected since visual observations indicate that the liquid samples collected in 1991 were clear with no obvious suspended solids.

The organic compounds acetone, diazinon, and simazine have been reported in Pond 207-C liquids. Acetone was also detected in analytical blanks, and may reflect laboratory contamination. Diazinon and simazine are both pesticides. Diazinon is an insecticide and nematicide used to control soil, crop and household pests, while simazine is a selective herbicide used to control annual grasses and broad leaf weeds.

Pond 207-C sludge was described in 1991 as a crystallized brownish-green solid with some sediment, ranging in thickness from 4 to 23 inches. The sludge consists primarily of sulfate, nitrate and fluoride salts of potassium and sodium. Other constituents occur as minor or trace constituents within these salts. Cyanide and phosphate occur at relatively high levels. Radionuclides are present in the sludge, but at concentrations several orders of magnitude lower than in the pond liquids. Transition metals, including cadmium, chromium, copper, iron and zinc, are also present. Nickel, which was present in Pond 207-C liquid, is absent in the sludge. No organic compounds were detected.

The liner of Pond 207-C is asphaltic concrete, and the original liner has been in use since 1970 when the pond was constructed. As evidenced in aerial photographs taken during the Pond 207-C construction, soil from the Original (clay-lined) Pond may have been used in construction of Pond 207-C. The pond is reported to be fitted with a leak detection system, although no information regarding leaks was available for use in this Work Plan. No contaminant data are available for soils underlying the liner. The integrity of the liner cannot be assessed until sludge and liquids are removed.

2.5.1.4 Contaminant Behavior

The chemical characteristics of wastes occurring within the Solar Ponds can be used to estimate their mobility in the environment and support the development of a conceptual model. Contaminant characteristics are discussed briefly in the following paragraphs to aid in understanding their affinity for different environmental media and their migration and transport behavior.

The alkali metal and alkaline earth elements, which include potassium, sodium, calcium and magnesium, occur abundantly in the natural environment. Lithium, which is also represented in the analyses of Solar Pond wastes, occurs in lesser natural abundance. These elements form the majority of dissolved cations both in wastewater and in ground and surface water solutions. At relatively high concentrations, such as those present in the Solar Ponds, they may precipitate from solution in association with the major anions as salts. Their relative concentrations may also influence soil characteristics through cation exchange and precipitation of caliche horizons. As major constituents in natural and waste waters, the relative concentrations of alkali metal and alkaline earth elements may also be used to identify waters from different sources.

Chloride, sulfate, carbonate and bicarbonate form the majority of anionic constituents found in natural waters, and are also observed in major concentrations in the Solar Ponds. Nitrate and fluoride, which occur naturally as minor constituents in ground and surface waters, also occur as major components in solar evaporation pond wastes. These major anions can combine with trace metals in solution to form complex ions, and at high concentrations can also limit the solubility of major cations and trace metals through the formation of solid precipitates. Examples of natural precipitates include sodium and calcium sulfates and calcium carbonate, which commonly form alkali deposits in closed evaporative basins and caliche horizons in arid soils. Similar precipitates form the inorganic sludges found in the Solar Ponds. These major anions are relatively mobile in solution, and can act as tracers of contaminated water in natural systems.

The transition metals occur naturally as trace constituents in soil, ground water and surface water, but may also be significant environmental contaminants as a result of their widespread use and potential toxicity. Cadmium, chromium, copper and nickel occur in solar evaporation pond liquids and sludges. Their background dissolved concentrations in local ground water and surface water have not been formally established, but are likely to be in the 1 to 10 part per billion range (Hem, 1985). Background concentrations of these transition metals in Rocky Flats soil have recently been developed in the Final Background Geochemical Characterization Report (EG&G, 1990d). Mobility of these metals is limited by adsorption to clays, organic matter, and iron oxyhydroxides present in soils. Solubility is also limited by the formation of oxide or hydroxide solids under sulfate conditions. Migration of the transition metals is therefore limited in the subsurface environment. Transport in association with particulates as suspended or bed load solids in surface water or as dust in air is common.

Radionuclides present in the Solar Ponds include both naturally occurring and man-made isotopes. These elements may be of concern due to both their radioactivity and chemical toxicity. The uranium isotopes occur naturally in soils and sediments, and exist in recoverable quantities near the Rocky Flats Plant. Their mobility is variable and is based primarily on environmental oxidation-reduction and pH conditions. Tritium is formed naturally by solar radiation in the upper atmosphere, although testing of nuclear weapons has far overshadowed this natural contribution to background activities. Tritium substitutes for hydrogen in the water molecule, and therefore acts as a conservative tracer when present in liquid wastes and introduced to the environment. Plutonium and americium are transuranic actinide elements, and do not occur naturally in the environment. As with tritium, however, sensitive analytical techniques allow measurement of background concentrations of these elements which result from atmospheric testing of nuclear weapons. Plutonium and americium both form insoluble hydroxide and oxide solids under neutral to basic pH conditions, rendering their mobility limited in the subsurface. Similar to the transition metals, however, plutonium and americium may be transported in association with particulates in surface water or air, or possibly as colloids in ground water. In addition, the presence of high concentrations of complexing anions may act to increase solubility.

Gross alpha and gross beta are composite measurements of all natural and anthropogenic radioactive constituents which decay by alpha and beta particle emission, respectively. Although useful for determining the potential exposure to a radioactive source, these measurements have limited application in evaluating contaminant state or mobility. They may provide an effective screening tool in estimating the presence of specific radionuclides of interest, and in identifying specific areas requiring detailed analysis.

2.5.1.5 Other Sources

Other potential sources of contamination include the Original Process Waste Lines (OPWL), which exist extensively in an underground network adjacent to the Solar Ponds. A map showing the presence of the OPWL in the Solar Ponds area is included in Appendix A. The OPWL network is contained within the separate Operable Unit 9 (OU9) and will be investigated separately. However, extensive coordination will be required in view of the overlapping nature of the OU9 and OU4.

2.5.2 Soils

The nature of contaminants in soils near the Solar Ponds were assessed using data obtained from three previous sampling programs conducted in 1986, 1987, and 1989. The location of all soil borings considered in this assessment are shown in Figure 2-23, where the soil sampling programs are differentiated by color.

The 1986 Field Investigation included split-spoon sampling of alluvium, bedrock and the bedrock/alluvium contact in five boreholes. These five boreholes are shown in red on Figure 2-23 and were later completed as Wells 1886, 2086, 2286, 2586 and 2786. The procedures followed during the 1986 sampling program are described in the Draft Work Plan, Geological and Hydrological Site Characterization. Sample analysis results for the 1986 soil borings are contained in Appendix C of the Solar Ponds Closure Plan (Rockwell International, 1988a).

The 1987 field program included collection of soil samples from 16 boreholes, SP01-87 through SP16-87, shown in green on Figure 2-23. Two of the boreholes were completed as monitoring wells; Borehole SP08-87 was completed as Well 3987, and SP16-87 as Well 5687. The procedures followed during the 1987 field investigation are described in the Comprehensive Environmental Assessment and Response Program (CEARP), Phase 2, Rocky Flats Plant, Installation Generic Monitoring Plan (Rockwell International, 1988a). Sample analysis results for the 1987 soil borings are contained in Appendix C of the Solar Ponds Closure Plan (Rockwell International, 1988a).

The 1989 soil investigation program at the Solar Ponds included sample collection from 20 boreholes, later completed as wells. The 1989 soil borings are shown in purple on Figure 2-23 and are denoted with the prefix P, the well number, and the 89 extension. The "P" series wells not shown on Figure 2-23 were not included in the soils assessment for this Work Plan.

The 1989 data were used not only to determine what contaminants were present near the Solar Ponds, but to conduct initial comparisons to data from the pond liquid and sludge. The comparisons allowed initial determinations to be made regarding the nature of contamination in the pond liquid and sludge and probable media relationships. Identified data gaps and the need to further evaluate media interactions will guide development of the field sampling plan presented in Section 7.0 of this Work Plan. The 1989 data were also used to reassess earlier conclusions made using 1986 and 1987 sample analysis results.

During the 1989 soil investigation, two to four soil samples were collected from each boring and analyzed for metals and inorganics. In addition, water samples were collected from those borings where ground water was encountered. Constituents detected in samples from the 1989 soil borings are presented in Table 2.12. Metals and inorganics were analyzed in all soil samples submitted for analysis, although radiological analyses were conducted on samples from only seven of the twenty 1989 borings. Organics were only analyzed in ground water samples from the 1989 program.

Sample analysis results were evaluated using statistically based background soil/vadose characteristics that are presented in the Final Background Geochemical Characterization Report (EG&G, 1990d). This background evaluation, conducted in 1989, involved a comprehensive collection of stream sediments, surficial alluvial and colluvial sediments, and bedrock material from uncontaminated areas of the buffer zone. This collection of samples includes nine stream sediment samples from nine locations, 70 alluvial sediment samples from nine locations, 28 colluvial sediment samples from nine locations, and 20 weathered bedrock samples from the nine colluvial sample locations. Four of the nine alluvial borings and four of the nine colluvial borings were drilled in the Northern Buffer Zone, and summary statistics were calculated for those data to independently evaluate North Rocky Flats.

Detailed statistical methods described in the Background Geochemical Characterization Report (EG&G, 1990d) were then applied to the observed concentrations soil data and statistical summaries were generated. Statistical summaries were prepared using the background samples in alluvial materials, and the samples from colluvial, weathered claystone and weathered sandstone. Summaries were prepared for North Rocky Flats, South Rocky Flats, and Rocky Flats as a whole. These statistical methods were used to generate a range of upper values for individual parameters. In this case, this upper range value was designated the upper tolerance limit. Concentrations of chemical parameters in soil boring samples were compared to these upper tolerance limits and evaluated more closely than results below the upper tolerance limit.

Because OU4 is located in the northeastern portion of the Rocky Flats Plant, data from the Solar Ponds and surrounding area were evaluated using the statistical summaries for the Rocky Flats North alluvial and weathered bedrock materials. Statistical summaries for Rocky Flats as a whole were also used for those compounds not calculated in the Rocky Flats North summaries. These statistical summaries are presented in Appendix E of this Work Plan.

The 1989 soil/vadose zone investigation supersedes background soil information collected in a 1986 study. In the 1986 Background Soil Investigation, limited samples were collected, and the establishment of a background value for a chemical parameter was taken as the upper range of values from those samples. The 1989 soil/vadose zone soil investigation was selected for use in evaluating soil data because it is statistically based and derived from a much larger data set than the 1986 investigation.

Selected analytical results from 1989 soil samples are summarized in Tables 2.13 and 2.14, and are compared on a relative basis to historical soil data presented in Appendix C of the Solar Evaporation Ponds Closure Plan (Rockwell International, 1988a). Data for these soil sampling programs were compared to established background values to evaluate potential anthropogenic contributions of naturally occurring elements, spatial trends were also investigated to determine possible source areas. Particular attention was paid to contaminants detected in pond liquids and sludges.

Major Anions

Nitrate concentrations in soil samples near the Solar Ponds exhibit strong relationships in both horizontal distance from the ponds and depth profile. Nitrate concentrations in soil are depicted in Figures 2-24 and 2-25, which presents soil analytical results for the sum of nitrate plus nitrite constituents as nitrogen. A review of samples for which both nitrate and nitrate plus nitrite data are available reveals that nitrate is the predominant nitrogen form present. Nitrate was detected in nearly all soil samples from near the Solar Ponds. Many of those borings located within approximately 50 feet of the pond perimeters exhibited relatively higher nitrate concentrations in near-surface samples. Borings located greater than 50 feet away tended to exhibit a nitrate contamination profile that increased with depth, appearing highest in vadose zone soils near the water table. The highest nitrate concentrations, greater than 1000 ppm in soils, were detected north and northeast and downgradient of Pond 207-B North in borings located adjacent to the inner boundary of the PSZ. This area corresponds to the location of ground water seeps which contain relatively high nitrate concentrations. A 1986 boring, located approximately 600 feet northeast of the borings containing highest nitrate, had concentrations less than 50 ppm.

Nitrate was detected in only a small percentage of background alluvial and weathered bedrock soil samples, and upper tolerance levels were not calculated for nitrate or nitrate/nitrite. The average nitrate concentration detected in background alluvial and weathered bedrock samples were less than 1 ppm. Concentrations detected in the vicinity of the Solar Ponds were as much as 3000 times greater than mean background concentrations.

Sludge and liquid samples from the Solar Ponds were found to contain relatively high nitrate concentrations. Releases from those ponds in the form of seepage and windblown aerosols, are the most likely sources of nitrate in the soil. The nitrate profile in soils is consistent with the behavioral geochemical characteristics of nitrate. Nitrate typically remains in solution as it infiltrates through the vadose zone and enters ground water. In areas of infiltration, wastewater, ground water seepage, or near the capillary fringe, relatively high soil nitrate concentrations would be anticipated due to presence of moisture containing high dissolved nitrate.

From a historical perspective, soil nitrate concentrations in the early 1970s were an order of magnitude higher than currently observed, and generally located near the surface (Rockwell International, 1988a). It is believed that the ITS has lowered the water table and allowed leaching of the near surface soils by precipitation.

Cyanide was detected in two 1987 borings located near the ponds. The highest cyanide concentrations were 8.7 ppm in the upper soils from a boring located between Pond 207-A and Pond 207-B South. Cyanide was detected at lower concentrations in two samples located north of Pond 207-B North and was below detection limit in all other 1986 and 1987 soil samples. Cyanide was not analyzed in 1989 samples. Pond 207-C and 207-A liquids contain high cyanide concentrations. The presence of cyanide in soils near Pond 207-A is probably indicative of release from this pond.

Sulfide, the only other major anion analyzed in soils was generally below detection limit, exhibited no distinct patterns indicative of solar evaporation pond contamination. The absence of sulfide also suggests the absence of strongly reducing conditions in soil.

Physical Parameters

Measurements of pH taken on all soil samples indicate a relatively neutral condition in the Solar Ponds area soil. Measurements of pH in ground water were similarly neutral. Mostly neutral pH measurements were obtained from water samples in the 1989 program. One slightly alkaline sample was collected from ground water in an area northeast of the ponds. This sample contained soil and ground water contaminants similar to pond liquids. Surface water pH measurements in the area were generally neutral.

Transition Metals

Cadmium was below detection limits in most soil samples from the area. One relatively high concentration was detected in a sample collected at a depth of 3 to 9 feet near the ponds, but no overall trends were observed. Cadmium concentrations in sludge ranged from 30 to over 10,000 ppm, but do not appear to have been released to surrounding soil.

Chromium in pond liquid and sludge samples were detected at relatively high concentrations of up to 17 ppm in liquid and up to 20,000 ppm in sludge. Chromium was detected in isolated soil samples, and may indicate mobility of chromium in the vicinity of the ponds. Chromium was present at 10 feet and greater in samples from two 1987 borings located near the 207-B series ponds, at concentrations nearly 40 times that which is indicated as background. Another sample from the 3 to 9 foot depth contained chromium at over 4 times background. These isolated occurrences suggest possible release of chromium in pond wastes but are not indicative of widespread mobility of chromium.

Copper was generally detected at concentrations similar to those detected in background samples. Copper was detected at one to four times greater than background in several 1989 borings located south and east of the Solar Ponds, and in two 1987 borings located on the pond perimeters. The highest concentration, 73.6 ppm was detected at 12 to 18 feet below the surface in a boring approximately 150 feet east of Pond 207-B Center. There is no apparent correlation between copper distribution in soil and copper in Solar Pond sludge and liquids.

Nickel was detected sporadically in samples throughout the Solar Pond area. The highest nickel content was 6 times the levels from background samples. Nickel was detected in liquids from all ponds with highest concentrations in Ponds 207-A and 207-C, but soil samples located on the perimeter of the pond were all below background. The low level nickel concentrations in the vicinity may be related to Solar Pond wastes.

Arsenic was detected in several samples from the 1987 and 1989 programs, at values ranging from 1 to approximately 14 times the concentrations indicated as representative of background conditions. The distribution of arsenic in these soil borings shows no direct correlation with the ponds, and may be attributable to geochemical variation in soils. The highest concentrations were from bedrock samples at a depth of approximately 20 feet. Liquid samples from the ponds contain less than 0.16 ppm arsenic and are not considered significant sources of soil contamination.

Concentrations of aluminum in soils ranged from one to three times the concentrations indicated as background for alluvial soils in the Rocky Flats vicinity. Aluminum was detected at low concentration in shallow soil samples in several borings within 100 feet of pond perimeters, suggesting that elevated aluminum in soils may be related to Solar Pond contamination. However, recent and historical data for sludge collected from the ponds indicated the presence of aluminum concentrations similar to or lower than those observed in alluvial soils. Release of these sludges should not result in increasing aluminum concentrations in soil.

Several surface samples from borings east and south of the Solar Ponds contained low concentrations of mercury, but mercury was not detected in samples collected closer to the ponds. Low level mercury is not attributed to Solar Pond contamination.

Other metals, including lead, selenium, thallium and zinc were either detected well below background, or were of relatively low concentration and showed no apparent relationship to Solar Pond liquids and sludges.

Alkali and Alkaline Earth Elements

Alkali metal and alkaline earth elements, including potassium, sodium, calcium and magnesium were detected in the vicinity of the Solar Ponds at levels higher than in buffer zone soils. Their widespread occurrence in this area is likely due to precipitation as salts from Solar Pond liquids released through seepage or as aerosols. Because these elements are relatively soluble and form significant percentages of the pond wastes, they may act as tracers of pond contamination, similar to nitrate. Potassium levels in soils were less than three times greater than levels indicated as background. Sodium content, which may be indicative of pond liquid metal precipitation was highest in samples collected above 10 feet in the Original Pond area, and northeast of the ponds. Sodium content was elevated only at 2 to 3 times values detected in background samples. Calcium content in Solar Ponds area soils was as much as 20 times greater than levels in background alluvial and background soils. The highest calcium levels occurred in soils less than 13 feet deep in soils east of the Solar

Ponds. Similarly, magnesium was found in soil samples east of the ponds. Magnesium was found in subsurface soils at levels less than three times the levels detected in background soils.

Lithium was detected in sludge from Pond 207-C at a maximum concentration of 43 ppm. In liquid, lithium was detected at highest concentrations in the 207-B ponds. Soil samples located adjacent to the 207-B ponds did not contain lithium above detection limits. Near surface samples south of Pond 207-C and in the Original Pond location did contain low levels of lithium, although they were only 2 to 3 times that which is indicated as background. There may be a relationship between lithium and the Original Pond based on these data.

Beryllium was detected at levels only 2 times greater than values indicated as background, and at various depths. Beryllium was detected at a maximum concentration of 1970 ppm in Pond 207-A sludge, although no clear relationship has been observed due to the low level, sporadic distribution in soils.

Barium was generally detected at concentrations of less than 2 to 3 times values indicated as background, with one exception. One elevated sample of 11,600 ug/g barium is approximately 150 times what is considered indicative of background. There is no apparent relationship to barium and Solar Pond contamination. Barium was generally undetectable in the Solar Pond sludge and liquid.

Radionuclides

Samples from seven borings in the 1989 program were submitted for radiochemistry analyses. A summary of the results of these analyses are in Table 2.14. Historical radiochemistry data are summarized in Table 2.15. Each data set was evaluated using the background geochemical report as a basis for comparison.

Tritium was detected in many samples near the pond perimeters, and in borings located east and northeast of the ponds. The tritium distribution patterns approximate those exhibited by nitrate. The highest concentrations of tritium are at depth, many from vadose zone samples at or near the water table. Tritium is found to have a positive correlation with nitrate, with many of the borings containing high nitrate also containing elevated tritium. The highest tritium concentration was nearly 100 times the value detected in buffer zone soils, but in general tritium concentrations were 3 to 5 times greater than tritium in buffer zone soils. Tritium is relatively mobile in vadose zone soils, as tritium substitutes for hydrogen in water molecules.

Distribution of gross alpha, which may provide indication of the presence of other radioisotopes, such as plutonium -239 or americium -241, did not indicate presence of alpha emitting radionuclides. Values of gross alpha from Solar Pond area soils were generally below the values indicated as background in the Final Background Geochemical Characterization Report (EG&G, 1990d). Only a few samples revealed gross alpha in excess of background. Similarly, gross beta values, which may indicate the presence of strontium-90 or cobalt -60 for example, were not at levels exceeding those in background samples.

Uranium-233 and -234 were detected at 1 to 3 times higher than background samples. The higher levels were typically in soil intervals at depth, but surficial samples near Pond 207-C also contained uranium -233 and -234. The Solar Ponds may contribute to uranium levels in the area, although contributions may also be received from other natural sources.

Uranium-238 was detected at a similar ratio to background samples, usually at 1 to 3 times higher. Levels were generally higher with depth, an observation than generally agrees with the background sample findings. Uranium -238 in background weathered bedrock samples was generally higher than in alluvial materials.

Plutonium-239 is widespread through the Solar Ponds area, and is detected almost exclusively in near-surface samples. Plutonium was detected in historical samples on the pond perimeters, in areas west and north of Pond 207-C, and northeast of Pond 207-B North. The highest levels were measured near Pond 207-C, near the Original Pond location. With these data, it is not evident that plutonium in this area is related solely to the Solar Ponds, or to widespread surficial plutonium in this portion of the Rocky Flats Plant. Plutonium-239 levels ranged from 5 to nearly 1000 times levels detected in background samples. The highest levels were near the Original Pond.

Americium-241, a decay product of plutonium, is distributed at the site much like plutonium. Americium-241 is found typically in the upper soil samples and is relatively widespread in the vicinity of the ponds. The higher surficial levels of americium were located in the vicinity of Pond 207-C, at activities from 25 to over 150 times greater than levels detected in background samples.

In June 1990, surficial soil sampling was conducted near Building 788 and Pond 207-A in response to increased plutonium concentration in air in this vicinity. Three soil samples collected June 20, 1990 and analyzed for plutonium and americium found an approximate americium to plutonium activity ratio of 2 to 1. Plutonium and americium levels were well above what was detected in soil samples from previous soil sampling programs. Maximum values obtained were 934 pCi/g americium and 438 pCi/g plutonium (see Appendix E). The data are currently undergoing validation, thus validated results were not available for use in this Work Plan. A copy of the telephone log documenting early conclusions of this study is provided in Appendix E.

The conclusions of the surficial sampling program near Pond 207-A prompted the conduct of a Field Instrument for Detection of Low-Energy Radiation (FIDLER) survey of the Solar Ponds embankments. The instrument counts alpha particle emission from surface soils and was used to determine distribution of the alpha emitters such as plutonium and americium. The FIDLER survey was conducted in August 1990, and readings from two FIDLER instruments were used to allow comparison of results. One-minute integrated counts were collected at background locations and on pond perimeters. Readings were taken at nearly 170 locations around the ponds. The survey found the area of Building 788 and Pond 207-A embankments to have elevated alpha counts relative to the Pond 207-C and 207-B series embankments; an indication of higher radionuclide content in Pond 207-A than the other ponds. A relatively isolated area between and east of Ponds 207-B Center and 207-B South also had elevated readings. A copy of the results from this FIDLER survey are in Appendix E.

Organics

No organic analyses are contained in the RFEDs database for soil samples from the 1989 program. Historically, analytical data for core samples collected in 1986 indicated the presence of low concentrations of methylene chloride, chloroform, acetone, 2-butanone, 1,1,-dichloroethane, 1,1,1-trichloroethane, trichloroethylene, toluene, and total xylene. In most cases, volatile organic compounds are at estimated concentrations below the positive quantitation limit and/or are present in the laboratory blanks. No analyses for laboratory blanks were included with the volatile organic analytical results for the 1987 samples, in which methylene chloride, chloroform and 2-butanone were detected. The volatile organics were generally near or below detection limits. Organic compounds were not detected at elevated concentrations in pond liquid and sludge samples, and organic compounds at the Solar Ponds are of less significance than the inorganics and radionuclides.

2.5.3 Ground Water

Ground water in the vicinity of the Solar Ponds is monitored within the site-wide RCRA Ground Water Monitoring Program and the RFP Groundwater Assessment Plan. Quarterly sampling is conducted under the RCRA program. Most of the RCRA ground water monitor wells correspond to the 1989 soil boreholes, as each borehole was later completed as a well. Data collected during the March 1990 sampling period or as close to that month as possible, were evaluated in this work plan to determine possible relationships to Solar Pond liquid, sludge and surrounding soil.

In addition to RCRA ground water program wells, ground water data collected during the 1989 soil boring program is considered on a relative basis. These data are presented in the RFEDs data base as GSEP series data, and are in Appendix F.

2.5.3.1 Alluvial Ground Water Quality

The alluvial ground water wells are indicated with an open circle on Figure 2-15. Ground water quality data for alluvial wells is presented in Appendix F and was taken from the 1990 Annual RCRA Ground Water Monitoring Report (EG&G, 1991d).

Distribution of nitrate in alluvial ground water generally correlates with distributions in soil. Figure 2-26 shows the nitrate/nitrite isoconcentration contours that were presented in the RCRA Ground Water Monitoring Report for First Quarter 1990. The combined nitrate plus nitrite analytical results are considered indicative of primarily nitrate in solution. The figure indicates highest nitrate concentrations to occur east of Ponds 207-B North and 207-B Center, whereas vadose zone soil data indicate the highest nitrate levels in areas are north and northeast of Pond 207-B North.

Volatile organic compounds were detected in alluvial ground water in an isolated area west of Pond 207-C. Soil from the borings drilled to construct these wells were not analyzed for volatile organics, but the source of these organic compounds is perhaps associated with the Original Pond, or from other upgradient sources.

Evidence of low levels of americium and strontium-90 are indicated by alluvial ground water results. Activities are relatively low and near detection limits. Strontium metal was present in several alluvial wells located east of the ponds, but the compound is not observed to be widespread in the alluvial ground water system.

Total dissolved solids were highest in the alluvial system east of the 207-B ponds in a pattern consistent with the nitrate distribution in vadose zone soil.

2.5.3.2 <u>Bedrock Ground Water Quality</u>

Ground water quality in the weathered bedrock system is characterized using the RCRA Ground Water Monitoring Program First Quarter 1990 Data (EG&G, 1991d). As with the alluvial water quality discussion, data obtained from water samples in the 1989 soil boring program were also considered on a relative basis. These data are included in Appendix F.

Nitrate in the weathered bedrock system is indicative of Solar Pond contamination due to its mobility through soils to ground water. The nitrate/nitrite distribution in weathered bedrock is indicated on Figure 2-27. As with the alluvial distribution figure for nitrate, the bedrock distribution correlates with the distribution in soils. High nitrate is found throughout the soil column in samples near the perimeters of the ponds with the highest concentrations being north and northeast of the ponds. Nitrate distribution follows the ground water flow path to the northeast.

Bedrock ground water nitrate isopleths depicted in Figure 2-27 were taken directly from the RCRA Annual Ground Water Monitoring Report for 1990. Current interpretations suggest the presence of elevated nitrate concentrations in a continuous plume extending from the ponds area toward the northeast.

Lithium was detected in several bedrock wells, with highest concentrations being north and northeast of the ponds. Tritium and strontium were detected throughout the weathered bedrock monitoring network, again increasing in concentration in the northeast, as well as exhibiting moderately high levels east of the ponds. Gross alpha was detected in a similar distribution pattern, at concentrations as much as 8 times greater than the 15 pCi/l maximum contaminant level for gross alpha in drinking water.

2.5.4 Surface Water Quality

Surface water sampling in the Solar Ponds area is summarized in the Solar Pond Interceptor Trench Study Ground Water Management Study Zero-Offsite Water Discharge (ASI, 1991).

Surface water in the northern vicinity of the Solar Ponds drains northward to North Walnut Creek, but is intercepted by the uncapped drains within the ITS. Surface water captured in the ITS mixes with intercepted ground water and is pumped back to Pond 207-B North. Concentrations in Pond 207-B North liquid vary with water fluctuation, evaporation rates, and other factors. Surface water monitoring stations are located both within the interceptor trench system and in the area north of the ponds.

Selected parameters detected in surface water from these stations are summarized on Figures 2-28 and 2-29. A number of parameters occur in surface water, in somewhat similar patterns. Nitrate and total dissolved solids were detected in highest concentrations from three sampling locations located north of Ponds 207-A and the 207-B ponds. Sampling stations north of Building 774 and Pond 207-C contained much lower concentrations of these parameters. Radionuclides plutonium-238 and americium -241 were detected in surface water throughout the area, the highest from surface water station 89 located between and immediately north of Ponds 207-A and 207-B North. Volatile organic compounds, primarily acetone, were detected in surface water samples located near Building 774, and from samples in and near the West Collector. Surface water in the area east of the ITS does not appear to be impacted by these contaminants (ASI, 1991).

Surface water samples collected downgradient of the ITS, in North Walnut Creek and the A-series ponds on North Walnut Creek in August 1986, July 1987 and November 1987, were analyzed for the Hazardous Substance List (HSL) volatile organics, semivolatiles, pesticides/PCBs, major inorganic ions, metals and radionuclides (Rockwell International, 1988a). The A-series ponds were constructed on North Walnut Creek to control surface water flow off the RFP site. Those analytes exceeding detection limits include manganese, thallium, iron, and total dissolved solids (TDS). The highest concentration of manganese, thallium, iron, and total dissolved solids occurs in samples collected from Pond A-2, and may reflect residual contaminants from past usage to store laundry effluents (Rockwell International, 1988a). In samples collected from Pond A-3, TDS and manganese exceeded the water quality criteria. However, discharges from Pond A-3 are in compliance with the conditions listed in the Plant's NPDES permit. Furthermore, at the most downgradient surface water station, SW-3 at Indiana Street (not shown on figures), all analyte concentrations are below the surface water quality criteria.

In the Solar Evaporation Ponds Closure Plan (Rockwell International, 1988a), it was concluded that degradation of surface water quality in North Walnut Creek is due, in part, to recharge by alluvial ground water in the vicinity of the Solar Ponds. However, containment of the flow by Pond A-3 and Pond A-4 with attendant reduction in analyte concentrations by natural processes, renders the quality of surface water leaving the RFP site acceptable with respect to the water quality criteria (Rockwell International, 1988a).

2.5.5 Air

Air monitoring data collected by Radioactive Ambient Air Monitoring Program (RAAMP) stations in the Solar Ponds area are contained in Appendix G. A map showing the locations of the RAAMPs is included with the data. Such data are collected on a routine basis and additional, more current data will be available for review as part of the first planning task of the Phase I RFI/RI program.

The highest plutonium concentrations have been detected from Stations 1, 5 and 8B with maximum average monthly values of 0.003197 pCi/m^3 for Station 1, 0.001389 pCi/m^3 for Station 5, and 0.000708 for 8B, based on the data in Appendix G.

2.6 SITE CONCEPTUAL MODEL

The site conceptual model is intended to describe known and suspected sources of contamination, types of contamination, affected media, contaminant migration pathways, and environmental receptors. The site conceptual model is used to assist in identifying sampling needs to obtain information for evaluating risks to human health and potential remedial alternatives. The site conceptual model is developed and based on the information presented previously and includes potential contaminant migration pathways from the Solar Ponds to other media or receptors. The conceptual model is used to express current understanding of the nature and distribution of contaminants and potential contaminant pathways. Thus, the conceptual model can be used to help guide the RFI/RI investigations by testing current understandings.

The Phase I RFI/RI, in accordance with the IAG, focuses on sources and soils (e.g., Solar Ponds liquids and sludges; liner material; surficial soils; and vadose zone materials) and, therefore, so does the conceptual model. However, to facilitate integration with the Phase II investigations, ground water, air, and biota are included in this conceptual model, even though they will be the primary focus of Phase II.

The primary source of contaminants in the Solar Ponds area are the process fluids piped to the ponds for storage and treatment. Fluids have been contained in the ponds since approximately 1953, and include the recent introduction of both treated sanitary wastewaters from the plant and ground water pumped back from the ITS. The liquids, sludges, and lining materials in the ponds are potential contaminant sources to the subsurface. Additional primary sources of contaminants in the Solar Ponds area include potential leakage from existing and abandoned pipelines, drainage from footing drains from nearby buildings, and the Original Pond in the vicinity of existing Pond 207-C.

The conceptual model is shown on Figure 2-30. The potentially affected media and contaminated migration pathways that are included in this Phase I RFI/RI Work Plan include:

- Surficial soils
- Subsurface soils of the vadose zone.

Not part of this Phase I RFI/RI Work Plan, but related as both sources and potential receptors, include process waste lines, surface water, ground water, and air. The potential interrelationships between those modes of contaminant transport and receptors are illustrated on Figure 2-31. Because they are related, a conceptual understanding of these transport modes is necessary to most effectively plan further investigations.

2.6.1 Pond Liquids and Sludges

The ponds are conceptualized as mixing vessels, open to the atmosphere, in which solar radiation increases the solids concentration to form a sludge of the mixture. The sludges are composed of crystalline wastes, algae and sediments. The liquids and sludges in the ponds are undergoing changes in chemistry through the mixture of different cations, anions, and suspended solids. These reactions are complicated by the evaporative process combined with periodic dilution by rainfall and snowmelt, volatilization, photochemical reactions, microbiological activity, and possible reaction with liner materials. These processes can transform both the liquid and solid chemical composition into additional dissolved and complexed chemical constituents that can potentially be transported through infiltration and percolation into the vadose zone and ground water system.

2.6.2 Surficial Soils

Soils in the vicinity of the Solar Ponds are potentially contaminated with aerosols from the ponds, contaminants from ground water seeps, and from other spatially related sources such as process waste lines that may not be distinguishable from the Solar Ponds. Contaminants in the surficial soils may be transported:

- Into the vadose zone and, ultimately, into the ground water system via infiltration of precipitation and/or leakage from the Solar Ponds
- Laterally, via surface runoff or as airborne fugitive dust.

The principle parameters that control the aforementioned transport are the chemical nature of the contaminants, particulate size and occurrence, and rate of infiltration from precipitation and/or leakage from the Solar Ponds.

2.6.3 Vadose Zone

The vadose zone is defined as the unsaturated subsurface depth interval from the surface to the water table, including perched ground water zones and multiple geologic/lithologic units. It is commonly termed the unsaturated zone but in the Solar Ponds Area, there may be perched ground water intervals and leakage zones that are saturated. Descriptions of the saturated status of soils in the Solar Ponds area indicate multiple saturated intervals within 25 feet of the ground surface which, in some cases, may be indicative of perched water. Exchanges between the vadose zone and ground water involve both the maximum and minimum depth interval of the fluctuating ground water level and the associated capillary fringe. The capillary fringe is a fluctuating depth interval of partial saturation that extends upward from the water table and it is included as part of the vadose zone. Perched water may flow laterally through overlying impermeable strata, and discharge at the surface as ground water seeps.

Both the Solar Ponds and surface soils are similar through their exposure to atmospheric physio-chemical conditions. These conditions can change abruptly in isolated sludges or in subsurface soils. Approximately one-third of the surface is covered by ponds, buildings, and roads that restrict the movement of oxygen from the atmosphere into the subsurface. Leakage from the ponds contains nutrients for microbial activity. The changes associated with processes such as microbial activity can affect the fate and transport of contaminants in the vadose zone. For example, the fate and transport of both transition metals and radionuclides are strongly dependent on pH and oxidation reduction potential (Eh) (Dragun, 1988) in both vadose zone water and ground water.

The ionic state of metals and radionuclides and the particle size of materials to which they are sorbed affects their transport in the subsurface. Laboratory and field investigations involving organic and inorganic ions indicate that the cationic ions (positively charged ions) and ionic complexes are removed or exchanged from solution much more effectively than anions (negatively charged ions). Also, recent research suggests that colloidal material is also a significant transport mechanism in the subsurface (Penrose et al., 1990).

2.6.4 Unconfined Ground Water System

Ground water is believed to be present in the Rocky Flats Alluvium, colluvium, and subcropping sandstones in the vicinity of the Solar Ponds under unconfined conditions. Depths to ground water are expected to vary from 0 to 25 feet below ground surface depending on location, antecedent precipitation, and time of year. Ground water flow is primarily toward the northeast.

Recharge to the unconfined ground water system in the vicinity of the Solar Ponds is expected to be primarily: (1) from infiltrating precipitation, and (2) leakage from the Solar Ponds. It is expected that contaminants in the liquids leaking from the pond(s) are carried downward into the vadose zone. Less mobile contaminants may become bound to soils, while soluble components will be transported to the water table. Contaminants that have spread laterally in the vadose zone are subject to subsequent downward migration from the leaching affect of infiltrating precipitation.

2.6.5 Surface Water and Sediments

Surface water provides a pathway for transporting potential contaminants from the Solar Ponds area. North Walnut Creek may receive contaminates from the pond leakage via lateral ground water flow, leaching from the vadose zone, and contaminated surficial soil transport by way of stormwater runoff. A series of dams, retention ponds, diversion structures, and ditches has been constructed at the Plant to control surface water, and to limit the potential for release of poor quality water. Some of the ponds are located in the drainages of North Walnut Creek. The creek and associated surface water control structures eventually lead to a reservoir, where the potential contaminants could be concentrated in sediments. The ability of contaminants to be bound to sediments or transported in the dissolved phase is dependent on both contaminant characteristics and environmental conditions.

The surface water system represents a potential route of exposure from ingestion/absorption/inhalation and dermal contact exposure routes. If present, dissolved and suspended transition metals, radionuclides, organics, and other contaminants may be released to, and transported by, the surface water system. Any volatiles present in surface water may be released to the atmosphere. Sediment from North Walnut Creek may currently act as an accumulation point for contaminants. These sediments may also be resuspended and diverted downstream during high flows.

2.6.6 Air

Air transmission of potential soil contaminants from the Solar Ponds may occur during the windy, dry periods of the year. Airborne release may also occur, to a limited extent, during site investigative activities or remedial actions if effective protective measures are not taken. Aerosols may be entrained in air from pond liquids during windy periods. Volatile organic compounds may also be released from pond liquids and sludges, as well as environmental media exposed to the atmosphere. Migration pathways correspond to local wind-flow patterns. Inhalation exposure is contingent on the proximity of receptor to the Solar Ponds area, although small particles, less than 10 microns in size, may be carried great distances. However, these particles will be well-dispersed and generally in low concentration. Surficial soils will be sampled to evaluate for possible contamination that could be transport as wind-blown dust.

2.6.7 Biota

Approximately two-thirds of the Solar Ponds area is located on open ground, without irrigation. The remaining one-third of the area is highly developed and includes the ponds, buildings, and pavements.

2.6.8 Receptors and Pathways

The ultimate estimate of the fate and transport of contaminants in the OU4 area depends on the acquisition of the data to properly interpret the sources(s), release(s), transport mechanism(s) and exposure pathways. Receptors are the populations exposed to contaminants at potential points of contact with a contaminated medium. Under current and future land use scenarios at OU4, human receptors include primarily plant workers, and secondarily, residents living near RFP. The primary pathways by which human receptors may potentially be exposed to contaminants include exposure to volatiles, windblown aerosols and dust, dermal contact with the surface water and sediments, ingestion and absorption of surface water and ground water, direct ingestion of surficial soils, ingestion of vegetation grown in soil, and consumption of wildlife.

Environmental receptors include vegetation, cold water game fish, migratory waterfowl and terrestrial mammals. These potential receptors could be exposed through the same routes as human receptors, with the exception of ground water.

2.6.9 Exposure Pathway Summary

One of the primary goals of the OU4 RFI/RI is to gather data to support a Baseline Risk Assessment which evaluates the potential risks of OU4 contamination to human health and the environment. The OU4 conceptual model developed in the preceding sections identifies potential completed exposure pathways resulting from OU4 releases. Data necessary to evaluate each of these pathways will be collected during the OU4 RFI/RI as described below.

- **Release → Soils → Ingestion or Dermal Contact:** Soils affected by Solar Pond releases may directly affect receptors through ingestion or dermal contact. Potential impacts of releases from contaminated soil to surface water will be identified and evaluated quantitatively using data collected for OU4 soils during the Phase I RFI/RI.

- **Release → Soils → Surface Runoff → Surface Water**: Soils affected by Solar Pond releases may serve as a source of contamination to surface water through flow across the ground surface. Affected surface water can impact receptors through mechanisms illustrated in Figure 2-30. Potential impacts of releases from contaminated soil to surface water will be identified using data collected for OU4 soils during the Phase I RFI/RI. These impacts will be evaluated quantitatively, if necessary, through surface water sampling and characterization during the Phase II RFI/RI.

- **Release → Soils → Volatilization/Evaporation → Air** and **Release → Soils → Wind Erosion → Air**: Soils affected by Solar Pond releases may serve as a source of contamination to air through volatilization/evaporation of contaminants or wind erosion of contaminated soils. Affected air can impact receptors through mechanisms illustrated in Figure 2-30. Potential impacts of releases from contaminated soil to air will be identified using data collected for OU4 soils during the Phase I RFI/RI. These impacts will be evaluated quantitatively, if necessary, through air sampling and characterization during the Phase II RFI/RI.

- **Release → Soils → Infiltration/Percolation → Groundwater** and **Release → Soils → Leaching → Groundwater**: Soils affected by Solar Pond releases may serve as a source of contamination to groundwater through infiltration/percolation of released liquids and through leaching and remobilization of contaminants to the water table by infiltrating groundwater. Affected groundwater can impact receptors through mechanisms illustrated in Figure 2-30. Potential impacts of releases from contaminated soil to groundwater will be identified using data collected for OU4 soils during the Phase I RFI/RI. These impacts will be evaluated quantitatively, if necessary, through groundwater sampling and characterization during the Phase II RFI/RI.

- **Release → Soils → Bioconcentration/Bioaccumulation → Biota** and **Release → Soils → Tracking → Biota**: Soils affected by Solar Pond releases may serve as a source of contamination to biota through direct biotic uptake from the soil (bioconcentration/bioaccumulation) and through physical contact (tracking). Affected biota can impact receptors through mechanisms illustrated in Figure 2-30. Potential impacts of releases from contaminated soil to biota will be identified using data collected for OU4 soils during the Phase I RFI/RI. These impacts will be evaluated quantitatively, if necessary, through biota sampling and characterization during the Phase II RFI/RI.

TABLE 2.1
COMPARISON OF HYDRAULIC PROPERTIES

Source	Formation	Hydraulic Conductivity cm/s
Ground Water Assessment Plan Addendum - Draft, EG&G, 1990.	Valley Fill	9×10^{-5}
	Alluvium	5.3×10^{-4} - 2.1×10^{-5}
	Bedrock	5.4×10^{-7} - 4×10^{-8}
Hydrogeological Characterization of the Rocky Flats Plant, Hydro-Search, 1985.	Alluvium	1×10^{-3}
	Arapahoe Sandstone	4×10^{-5}
	Arapahoe Claystone	3×10^{-7}
Section E Groundwater Protection, Rockwell International, 1986.	Rocky Flats Alluvium	7×10^{-5}
	Walnut Creek Alluvium	3×10^{-5}
	Woman Creek Alluvium	3×10^{-3}
	Arapahoe Sandstone	2×10^{-6}
	Weathered Arapahoe Claystone	5×10^{-7}
	Unweathered Arapahoe Claystone	1×10^{-7}
	Qal (Valley Fill)	2×10^{-4}
Draft Final Groundwater Protection and Monitoring Plan, EG&G, 1991.	Rocky Flats Alluvium Arapahoe Sandstone #1	6×10^{-5}
	Arapahoe Sandstone #3, 4, 5	10^{-6}
	Basal Arapahoe Sandstone	10^{-6}
	Arapahoe Claystone (Weathered and Unweathered)	10^{-7} - 10^{-8}
RCRA Part B Permit Application, Rockwell International, 1988.	Rocky Flats Alluvium	7×10^{-5}
	Valley Fill	3×10^{-3}
	Arapahoe Formation	2×10^{-6} - 1×10^{-7}
Hydrology of a Nuclear-Processing Plant Site, Hurr, 1976.	Rocky Flats Alluvium	1×10^{-2}
	Valley Fill	NA
	Arapahoe Formation	1×10^{-4}
RCRA Post Closure Care Permit Application, Rockwell International, 1988.	Rocky Flats Alluvium	9×10^{-6} - 4×10^{-8}
	Valley Fill	5×10^{-6}
	Arapahoe Formation	NA

SOURCE: 1990 Annual RCRA Groundwater Monitoring Report (EG&G, 1991d).

TABLE 2.2

FIRST QUARTER 1990 WATER LEVELS IN SURFICIAL MATERIALS

COLLUVIAL WELLS	1/90 (ft)	2/90 (ft)	3/90 (ft)
B208789	5897.58	5897.41	N/A
B208389	DRY	N/A	N/A
B210489	5853.71	5853.79	N/A
1886	DRY	N/A	N/A
P209989	DRY	N/A	N/A
B208089	5923.20	N/A	N/A
2086	DRY	DRY	N/A
3386	DRY	DRY	N/A
2187	5919.01	5919.67	DRY
ALLUVIAL WELLS	**1/90 (ft)**	**2/90 (ft)**	**3/90 (ft)**
P209289	DRY	N/A	N/A
2886	5955.27	5955.02	N/A
2286	5967.79	5967.51	N/A
5687	5970.68	5970.79	N/A
P207889	5957.73	5957.68	N/A
2986	DRY	N/A	N/A
P209789	5956.12	N/A	5961.60
3787	5960.04	N/A	5962.81
P207689	5959.39	N/A	N/A
2686	5964.92	DRY	N/A
2486	DRY	N/A	N/A
P207489	N/A	N/A	N/A
3887	5963.15	5963.00	N/A
0460	5965.13	N/A	5972.02
VALLEY FILL WELLS	**1/90 (ft)**	**2/90 (ft)**	**3/90 (ft)**
B208589	5853.45	N/A	5854.52
1586	5841.06	5841.12	N/A
1386	5834.44	5834.50	N/A
3686	5878.07	N/A	N/A
3586	5902.19	N/A	N/A

TABLE 2.2

FIRST QUARTER 1990 WATER LEVELS IN SURFICIAL MATERIALS
(continued)

COLLUVIAL WELLS	1/90 (ft)	2/90 (ft)	3/90 (ft)
1786	5958.94	5860.32	N/A

NOTES: 1. See Figure 2-15 for well locations in the Solar Evaporation Ponds Area.
2. Datum is mean sea level.
3. N/A is defined as Not Available.

SOURCE: 1990 Annual RCRA Groundwater Monitoring Report (EG&G, 1991d).

TABLE 2.3

THIRD QUARTER 1990 WATER LEVELS IN SURFICIAL MATERIALS

COLLUVIAL WELLS	7/90 (ft)	8/90 (ft)	9/90 (ft)
B208789	5895.31	5895.07	5895.35
B208389	DRY	DRY	N/A
B210489	5852.91	N/A	N/A
1886	DRY	DRY	DRY
P209989	DRY	DRY	DRY
B208089	5924.09	5924.11	5923.84
2086	5950.21	DRY	DRY
3386	5942.41	DRY	N/A
2187	5920.67	DRY	5922.94
ALLUVIAL WELLS	**7/90 (ft)**	**8/90 (ft)**	**9/90 (ft)**
P209289	DRY	5968.77	5969.04
2886	5956.99	5956.93	5956.16
2286	N/A	5969.19	N/A
5687	5972.40	5970.57	5971.78
P207889	5959.16	N/A	N/A
2986	DRY	DRY	DRY
P209789	5957.83	N/A	N/A
3787	5962.15	5961.62	5961.30
P207689	5960.20	N/A	N/A
2686	5965.31	5965.23	5964.96
2486	DRY	DRY	DRY
P207489	5975.35	5975.04	5974.65
3887	5964.28	5964.02	N/A
0406	N/A	5966.15	N/A
VALLEY FILL WELLS	**7/90 (ft)**	**8/90 (ft)**	**9/90 (ft)**
B208589	5882.52	N/A	N/A
1586	5840.90	N/A	N/A
1386	5832.27	5832.62	5930.02
3686	5876.36	5876.12	N/A
3586	5903.04	5902.34	N/A

TABLE 2.3

THIRD QUARTER 1990 WATER LEVELS IN SURFICIAL MATERIALS
(continued)

COLLUVIAL WELLS	7/90 (ft)	8/90 (ft)	9/90 (ft)
1786	5860.10	5860.07	5860.04

NOTES: 1. See Figure 2-15 for well locations in the Solar Evaporation Ponds Area.
2. Datum is mean sea level.
3. N/A is defined as Not Available.

SOURCE: 1990 Annual RCRA Groundwater Monitoring Report (EG&G, 1991d).

TABLE 2.4

SOLAR EVAPORATION PONDS
CONSTRUCTION DETAILS FOR THE MONITORING WELLS

Well No.	Completion Zone[4]	Screened Interval (ft.)[3]	Borehole Total Depth (ft.)[3]	Surface Elevation[3]
0260	Kacl(w)[1]	NA	NA	5934.60
0460	Qrf[1]	NA	NA	5962.00
1386	Qvf[1]	3.09-9.50	15.50	5837.22
1486	Kass(u)[1]	39.42-55.36	74.00	5844.71
1586	Qvf[1]	4.09-14.69	18.00	5845.61
1686	Kass(u)[1]	39.06-45.06	64.00	5864.74
1786	Qvf[1]	3.73-13.98	19.20	5865.26
1886	Qc[1]	3.74-7.50	10.50	5882.82
1986	Qc[2]	3.00-12.25	16.50	5946.00
2086	Qc[1]	4.21-10.55	22.00	5960.47
2186	Qc[1]	35.00-67.24[4]	78.00	5991.11[4]
2286	Qrf[1]	3.20-11.20	26.00	5976.81
2386	Kass(u)[1]	113.00-117.25	130.50	5981.18
2486	Qrf[1]	2.95-7.45	12.00	5980.45
2586	Kass(u)[1]	59.90-82.00	89.80	5974.45
2686	Qrf[1]	3.75-11.00	17.00	5974.48
2786	Kass(u)[1]	128.50-133.00	157.00	5961.86
2886	Qrf[1]	4.03-8.60	15.50	5961.23
2986	Qrf[1]	2.83-8.77	22.50	5958.26
3086	Kacl(w)[1]	2.48-14.93	16.00	5956.21
3186	Kass(w)[1]	2.46-17.32	22.00	5964.21
3286	Kass(u)[1]	114.90-125.50	135.00	5964.46
3386	Qc[2]	2.99-7.34	16.80	5949.28
0387	Qd/Qrf	102.80-108.00	117.00	5930.58
0487	Qd/Qrf	3.50-6.70	13.00	5882.69
SP0687	Qaf/Qrf[2]	NA	30.70	5972.90

TABLE 2.4

SOLAR EVAPORATION PONDS
CONSTRUCTION DETAILS FOR THE MONITORING WELLS
(continued)

Well No.	Completion Zone[4]	Screened Interval (ft.)[3]	Borehole Total Depth (ft.)[3]	Surface Elevation[3]
SP0787	Qaf/Qrf[2]	NA	31.00	5973.60
SP0887	Qd/Qc[2]	109.99-117.39	140.00	5947.10
SP0987	Qd/Qc[2]	NA	11.00	5945.00
SP1087	Qd/Qc[2]	NA	22.70	5941.00
SP1187	Qd/Qc[2]	NA	34.00	5904.50
3787	Qd/Qrf[2]	3.50-12.50	13.00	5967.03
3887	Qd/Qrf[2]	3.50-9.50	14.00	5971.79
3987 (SP0887)	NA	109.99-117.39	140.00	5947.10
5087 (SP1687)	Qd/Qrf[2]	3.52-9.92	13.40	5978.51
P207389	Kass(w)	10.53-15.18	23.30	5981.02
P207489	Qrf	2.39-7.00	10.00	5980.71
P207589	Kacl	14.40-23.86	29.10	5974.06
P207689	Qrf	3.64-13.10	18.20	5966.32
P207789	Kacl	17.90-27.34	32.30	5965.88
P207889	Qrf	3.26-7.70	10.50	5962.82
P207989	Kacl	11.00-20.48	26.20	5963.09
B208089	Qc	3.40-12.90	22.20	5935.40
B208189	Kacl	16.90-26.34	32.50	5935.40
B208289	Kacl	5.95-15.42	19.00	5850.70
B208389	Qc	3.37-7.30	16.30	5876.80
B208489	Kacl	19.76-29.22	33.20	5876.30
B208589	Qvf	3.23-3.99	9.60	5856.50
B208689	Kacl	12.32-21.80	28.40	5867.60
B208789	Qvf	2.88-10.93	14.40	5907.10
P208889	Kass(u)	87.76-96.94	105.70	5947.30
P208989	Kacl	15.40-25.80	28.60	5962.53
P209089	Kacl	16.50-25.96	31.50	5972.16

TABLE 2.4

SOLAR EVAPORATION PONDS
CONSTRUCTION DETAILS FOR THE MONITORING WELLS
(continued)

Well No.	Completion Zone[4]	Screened Interval (ft.)[3]	Borehole Total Depth (ft.)[3]	Surface Elevation[3]
P209189	Kass(w)	13.30-35.01	38.30	5980.66
P209289	Qrf	8.20-12.66	17.80	5981.59
P209389	Kass(w)	16.82-28.80	34.20	5981.47
P209489	Kass(w)	15.48-35.00	48.00	5977.98
P209589	Kacl	9.07-18.52	30.30	5948.17
P209689	Kacl	17.20-26.67	30.20	5962.63
P209789	Qrf	3.00-12.50	17.50	5962.82
P209889	Kacl	8.89-18.83	23.90	5940.28
P209989	Qc	3.81-8.18	12.00	5898.10
P210089	Kacl	12.20-21.50	28.00	5898.40
P210189	Kass(w)	20.40-36.50	38.60	5980.82
P210289	Kacl	11.57-21.00	26.00	5967.03
B210389	Kacl	13.61-23.07	28.50	5873.20
B210489	Qc	2.98-7.41	28.10	5856.40
P213789	Qrf[2]	2.46-6.90	9.60	5917.80
P213889	Qrf[2]	11.30-20.83	31.85	5954.10
P213989	Qrf[2]	3.29-6.92	9.70	5954.30
P219089	Qrf[2]	5.00-14.44	20.00	5949.10
P219189	Qrf[2]	7.08-11.90	21.00	5941.20
P219489	Qrf[2]	18.48-22.90	32.00	5959.50

1 1990 Annual RCRA Groundwater Monitoring Report, 1991, Volume I
2 EG&G Geologic Characterization, 1991
3 Well Completion and Geologic Logs from Rockwell International, Closure Plan, 1988, Volume III or Summary of Field Activities, EG&G 1990
4 Completion Zone Information from Summary of Field Activities, EG&G 1990, except where noted.

TABLE 2.4

**SOLAR EVAPORATION PONDS
CONSTRUCTION DETAILS FOR THE MONITORING WELLS**
(continued)

KEY:

Qaf	Artificial Fill
Qd	Disturbed Ground
Qrf	Rocky Flats Alluvium
Qc	Colluvium
Qvf	Valley Fill Alluvium
Kacl & Kacl(w)	Weathered Arapahoe Formation Claystone
Kass(w)	Weathered Arapahoe Formation Sandstone
Kass(u)	Unweathered Arapahoe Formation Sandstone
NA	Not Available

TABLE 2.5

FIRST QUARTER 1990 WATER LEVELS IN WEATHERED BEDROCK

SITE	1/90 (ft)	2/90 (ft)	3/90 (ft)
0260	5922.31	N/A	5929.02
3086	5952.02	5952.09	N/A
3186	DRY	N/A	N/A
B208189	5915.84	5917.28	N/A
B208289	5835.87	5934.93	N/A
B208689	5859.60	N/A	5860.23
B210389	5851.81	5852.41	N/A
B207389	5974.94	N/A	5976.83
P207789	5939.11	5939.22	N/A
P207989	5948.09	5948.71	N/A
P209389	5963.83	N/A	5967.14
P209489	DRY	N/A	N/A
P209589	5932.05	N/A	N/A
P209689	5936.24	N/A	5936.83
P209889	5937.25	N/A	5937.88
P210089	5881.71	5881.57	N/A
P210189	5967.65	N/A	N/A
P210289	5950.92	N/A	5953.44
P213889	DRY	N/A	N/A

Notes: 1. See Figure 2-15 for well locations in the Solar Evaporation Ponds Area.
2. Datum is mean sea level.
3. N/A is defined as Not Available.

SOURCE: 1990 Annual RCRA Groundwater Monitoring Report (EG&G, 1991d).

TABLE 2.6

THIRD QUARTER 1990 WATER LEVELS IN WEATHERED BEDROCK

SITE	7/90 (ft)	8/90 (ft)	9/90 (ft)
0260	N/A	5929.40	N/A
3086	5951.97	5952.20	N/A
3186	DRY	N/A	N/A
B208189	N/A	5912.45	5914.08
B208289	5835.84	N/A	N/A
B208689	5853.35	N/A	N/A
B210389	N/A	N/A	5852.20
B207389	5975.80	5975.23	N/A
P207789	5938.22	5938.71	N/A
P207989	5946.98	5949.48	N/A
P209389	5964.89	5965.85	N/A
P209489	5951.42	5951.52	N/A
P209589	5931.02	5929.26	N/A
P209689	5935.80	N/A	N/A
P209889	5937.34	5937.40	N/A
P210089	5879.69	5881.66	N/A
P210189	5969.12	5970.05	N/A
P210289	5951.51	N/A	N/A
P213889	DRY	DRY	DRY

Notes: 1. See Figure 2-15 for well locations in the Solar Evaporation Ponds Area.
2. Datum is mean sea level.
3. N/A is defined as Not Available.

SOURCE: 1990 Annual RCRA Groundwater Monitoring Report (EG&G, 1991d).

TABLE 2.7

SOLAR EVAPORATION POND 207A
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

Compound	Units	207A Liquid		207A Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
ANIONS					
Ammonia	ppm	NA	0.43	NA	NA
Bicarbonate	ppm	NA	35	NA	NA
Carbonate	ppm	NA	47	NA	NA
Chloride	ppm	NA	416	NA	NA
Cyanide, Total	ppm	ND - 1.7	0.478	NA	NA
Fluoride	ppm	NA	ND	NA	NA
Nitrate, N	ppm	ND - 21,739	1000	8800	NA
Nitrite	ppm	NA	39	NA	NA
Phosphate, Ortho	ppm	NA	ND	NA	NA
Phosphate, Total	ppm	NA	ND	NA	NA
Sulfate	ppm	NA	409	NA	NA
Sulfide	ppm	NA	ND	NA	NA
TKN-N	ppm	NA	ND	NA	NA
RADIONUCLIDES					
Americium -241	pCi/l	ND - 200	0.42	NA	NA
Americium -241	pCi/g	NA	NA	1400-4400	NA
Plutonium -239	pCi/l	ND - 660	0.71	ND	NA
Plutonium -239	pCi/g	NA	NA	1000-3700	NA
Uranium -234	pCi/l	14000-20000	310	NA	NA
Uranium -234	pCi/g	NA	NA	70-570	NA
Uranium -235	pCi/l	NA	11	28-28	NA
Uranium -235	pCi/g	NA	NA	28-28	NA
Uranium -238	pCi/l	21000-28000	340	520-520	NA
Uranium -238	pCi/g	NA	NA	130-480	NA

TABLE 2.7

SOLAR EVAPORATION POND 207A
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207A Liquid		207A Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Uranium	pCi/l	0.7-26000	ND	NA	NA
Tritium	pCi/l	240-3000	NA	NA	NA
Tritium	pCi/g	NA	NA	1300-12000	NA
Gross Alpha	pCi/l	32-80000	300	NA	NA
Gross Beta	pCi/l	2-40000	930	NA	NA
MISCELLANEOUS TESTS					
Alkalinity, Total	ppm	NA	110	NA	NA
Conductivity @ 25C	uMHOs	NA	8800	NA	NA
Total Dissolved Solids	ppm	127000-127000	7600	NA	NA
Total Organic Carbon	ppm	NA	67.8	NA	NA
Total Suspended Solids	%	NA	23	NA	NA
pH	ppm	8.3-11	9.9	9.5	NA
METALS					
Aluminum	ppm	2.31-2.64	ND	11000-11900	NA
Antimony	ppm	NA	ND	NA	NA
Arsenic	ppm	0.015-0.015	ND	ND	NA
Barium	ppm	ND	NA	ND	NA
Beryllium	ppm	ND-0.1	NA	309-1570	NA
Bismuth	ppm	NA	ND	NA	NA
Boron	ppm	NA	1.26	NA	NA
Cadmium	ppm	0.070-0.150	ND	1110-10500	NA
Calcium	ppm	ND	60.4	19600-50000	NA
Cerium	ppm	NA	NA	NA	NA
Cesium	ppm	NA	NA	NA	NA
Cobalt	ppm	0.200-0.500	NA	ND	NA
Chromium, Total	ppm	13.7-16.7	ND	1010-19700	NA

TABLE 2.7

SOLAR EVAPORATION POND 207A
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207A Liquid		207A Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Chromium, Hexavalent	ppm	NA	NA	ND-1.0	NA
Copper	ppm	1.61-1.8	ND	425-1590	NA
Germanium	ppm	NA	NA	NA	NA
Iron	ppm	1.5-8.0	ND	3590-6900	NA
Lead	ppm	ND	0.004	65-455	NA
Lithium	ppm	NA	1.42	NA	NA
Magnesium	ppm	ND	121	6100-21000	NA
Manganese	ppm	0.095-0.115	ND	153-595	NA
Mercury	ppm	ND-0.0002	ND	7.5-25	NA
Molybdenum	ppm	NA	ND	NA	NA
Nickel	ppm	1.9-2.0	ND	124-1320	NA
Niobium	ppm	NA	NA	NA	NA
Phosphorous	ppm	NA	NA	NA	NA
Potassium	ppm	13200-14300	376	50000-65300	NA
Rubidium	ppm	NA	NA	NA	NA
Selenium	ppm	ND	0.015	ND	NA
Silicon	ppm	NA	0.846	NA	NA
Silver	ppm	NA	ND	153-237	NA
Sodium	ppm	36300-42900	1610	130000-166000	NA
Strontium	ppm	NA	2.35	NA	NA
Tantalum	ppm	NA	NA	NA	NA
Tellurium	ppm	NA	NA	NA	NA
Thallium	ppm	NA	ND	NA	NA
Thorium	ppm	NA	NA	NA	NA
Tin	ppm	7-13	ND	ND	NA
Titanium	ppm	NA	NA	NA	NA

TABLE 2.7

SOLAR EVAPORATION POND 207A
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207A Liquid		207A Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Tungsten	ppm	NA	NA	NA	NA
Vanadium	ppm	0.10-0.20	NA	NA	NA
Zirconium	ppm	NA	NA	NA	NA
Zinc	ppm	0.62-0.78	0.028	227-595	NA
VOLATILE ORGANICS					
Acetone	ppb	100-260	3.0	5-4680	NA
Methylene Chloride	ppb	ND	5.0	ND	NA
Tetrachloroethene	ppb	ND	ND	ND-1200	NA
SEMIVOLATILE					
Acenaphthene	ppb	NA	ND	NA	NA
Bis(2-ethylhexyl) phthalate	ppb	NA	ND	ND-14900	NA
4-Chloro-3-methylphenol	ppb	NA	ND	NA	NA
2-Chlorophenol	ppb	NA	ND	NA	NA
1,4-Dichlorobenzene	ppb	NA	ND	NA	NA
2,4-Dinitrotoluene	ppb	NA	ND	NA	NA
Di-n-butyl phthalate	ppb	NA	ND	ND-590	NA
Fluoranthene	ppb	NA	ND	161-1680	NA
N-Nitroso-di-propylamine	ppb	NA	ND	NA	NA
Phenol	ppb	NA	ND	NA	NA
Phenols, Total	ppb	13-35	NA	ND-3300	NA
Pyrene	ppb	NA	ND	NA	NA
1,2,4-Trichlorobenzene	ppb	NA	ND	NA	NA
PESTICIDES/PCBs					
Atrazine	ppb	NA	3.5	NA	NA
Diazinon	ppb	NA	ND	NA	NA
Simazine	ppb	NA	ND	NA	NA

TABLE 2.7

SOLAR EVAPORATION POND 207A
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

References: Rockwell International, 1988a, Solar Evaporation Ponds Closure Plan
Dames and Moore, 1991, A Summary of Chemical Analyses of Sludge and Water

NA -- Not Analyzed
ND -- Not Detected

TABLE 2.8

**SOLAR EVAPORATION POND 207B (NORTH)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS**

Compound	Units	207B (North) Liquid		207B (North) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
ANIONS					
Ammonia	ppm	NA	ND	NA	102
Bicarbonate	ppm	NA	ND	NA	ND
Carbonate	ppm	NA	ND	NA	ND
Chloride	ppm	NA	147	NA	1910
Cyanide, Total	ppm	NA	37.8	NA	ND
Fluoride	ppm	NA	ND	NA	ND
Nitrate, N	ppm	212 - 1367	39	NA	600
Nitrite	ppm	NA	ND	NA	10
Phosphate, Ortho	ppm	NA	ND	NA	4
Phosphate, Total	ppm	NA	0.04	NA	ND
Sulfate	ppm	NA	155	NA	ND
Sulfide	ppm	NA	ND	NA	56
TKN-N	ppm	NA	ND	NA	1430
RADIONUCLIDES					
Americium -241	pCi/l	ND	0.14	NA	ND
Americium -241	pCi/g	NA	NA	NA	NA
Plutonium -239	pCi/l	ND	ND	NA	2.2
Plutonium -239	pCi/g	NA	NA	NA	NA
Uranium -234	pCi/l	50 - 53	40	NA	13
Uranium -234	pCi/g	NA	NA	NA	NA
Uranium -235	pCi/l	NA	1.7	NA	0.4
Uranium -235	pCi/g	NA	NA	NA	NA
Uranium -238	pCi/l	31 - 33	26	NA	8.4
Uranium -238	pCi/g	NA	NA	NA	NA

TABLE 2.8

SOLAR EVAPORATION POND 207B (NORTH)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207B (North) Liquid		207B (North) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Uranium	pCi/l	NA	ND	NA	ND
Tritium	pCi/l	1200 - 1300	NA	NA	NA
Tritium	pCi/g	NA	NA	NA	NA
Gross Alpha	pCi/l	13 - 323	59	NA	33
Gross Beta	pCi/l	5 - 200	110	NA	46
MISCELLANEOUS TESTS					
Alkalinity, Total	ppm	NA	75	NA	290
Conductivity @ 25C	uMHOs	NA	3380	NA	589
Total Dissolved Solids	ppm	NA	3200	NA	NA
Total Organic Carbon	ppm	NA	7.6	NA	11000
Total Suspended Solids	%	NA	18	NA	26
pH	ppm	7.5 - 9.6	8.5	NA	7.3
METALS					
Aluminum	ppm	ND - 1.00	ND	NA	4140
Antimony	ppm	ND	ND	NA	ND
Arsenic	ppm	ND	ND	NA	ND
Barium	ppm	ND - 0.22	ND	NA	NA
Beryllium	ppm	ND - 0.06	NA	NA	NA
Bismuth	ppm	ND	ND	NA	ND
Boron	ppm	0.09 - 0.31	0.173	NA	ND
Cadmium	ppm	ND - 0.01	ND	NA	12
Calcium	ppm	20 - 290	189	NA	247000
Cerium	ppm	ND	NA	NA	NA
Cesium	ppm	ND	NA	NA	NA
Cobalt	ppm	ND	NA	NA	NA
Chromium, Total	ppm	ND	ND	NA	33

TABLE 2.8

SOLAR EVAPORATION POND 207B (NORTH)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207B (North) Liquid		207B (North) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Chromium, Hexavalent	ppm	NA	NA	NA	NA
Copper	ppm	ND	ND	NA	ND
Germanium	ppm	ND	NA	NA	NA
Iron	ppm	ND - 0.29	ND	NA	4530
Lead	ppm	ND - 0.004	ND	NA	12
Lithium	ppm	0.37 - 6	0.332	NA	ND
Magnesium	ppm	66 - 120	79.3	NA	4670
Manganese	ppm	ND - 0.015	ND	NA	80
Mercury	ppm	ND	ND	NA	ND
Molybdenum	ppm	ND - 0.0069	ND	NA	ND
Nickel	ppm	ND - 0.05	ND	NA	ND
Niobium	ppm	ND	NA	NA	NA
Phosphorous	ppm	ND	NA	NA	NA
Potassium	ppm	56 - 120	58.8	NA	ND
Rubidium	ppm	ND	NA	NA	NA
Selenium	ppm	ND - 0.024	0.008	NA	ND
Silicon	ppm	ND - 5.6	1.02	NA	2670
Silver	ppm	ND - 0.082	ND	NA	ND
Sodium	ppm	363 - 820	403	NA	ND
Strontium	ppm	0.14 - 3.5	2.22	NA	692
Tantalum	ppm	ND	NA	NA	NA
Tellurium	ppm	ND	NA	NA	NA
Thallium	ppm	ND	ND	NA	7
Thorium	ppm	ND	NA	NA	NA
Tin	ppm	ND	ND	NA	ND
Titanium	ppm	ND	NA	NA	NA

TABLE 2.8

SOLAR EVAPORATION POND 207B (NORTH)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207B (North) Liquid		207B (North) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Tungsten	ppm	ND	NA	NA	NA
Vanadium	ppm	ND	NA	NA	NA
Zirconium	ppm	ND	NA	NA	NA
Zinc	ppm	ND - 0.022	0.048	NA	101
VOLATILE ORGANICS					
Acetone	ppb	ND	ND	NA	ND
Methylene Chloride	ppb	19-71	ND	NA	ND
Tetrachloroethene	ppb	ND	ND	NA	ND
SEMIVOLATILE					
Acenaphthene	ppb	NA	ND	NA	4500
Bis(2-ethyl hexyl) phthalate	ppb	NA	ND	NA	NA
4-Chloro-3-methylphenol	ppb	NA	ND	NA	7900
2-Chlorophenol	ppb	NA	ND	NA	7700
1,4-Dichlorobenzene	ppb	NA	ND	NA	4000
2,4-Dinitrotoluene	ppb	NA	ND	NA	3500
Di-nbutyl phthalate	ppb	NA	ND	NA	ND
Fluoranthene	ppb	NA	ND	NA	ND
N-Nitroso-di-propylamine	ppb	NA	ND	NA	3900
Phenol	ppb	NA	ND	NA	7400
Phenols, Total	ppb	3 - 46	NA	NA	NA
Pyrene	ppb	NA	ND	NA	4600
1,2,4-Trichlorobenzene	ppb	NA	ND	NA	4300
PESTICIDES/PCBs					
Atrazine	ppb	NA	1.1	NA	ND
Diazinon	ppb	NA	ND	NA	ND
Simazine	ppb	NA	ND	NA	ND

TABLE 2.8

**SOLAR EVAPORATION POND 207B (NORTH)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS**
(continued)

References: Rockwell International, 1988a, Solar Evaporation Ponds Closure Plan
Dames and Moore, 1991, A Summary of Chemical Analyses of Sludge and Water

NA -- Not Analyzed
ND -- Not Detected

TABLE 2.9

**SOLAR EVAPORATION POND 207B (CENTER)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS**

Compound	Units	207B (Center) Liquid		207B (Center) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
ANIONS					
Ammonia	ppm	NA	0.5	NA	135
Bicarbonate	ppm	NA	ND	NA	ND
Carbonate	ppm	NA	280	NA	ND
Chloride	ppm	NA	763	NA	11200
Cyanide, Total	ppm	NA	0.555	NA	ND
Fluoride	ppm	NA	73	NA	ND
Nitrate, N	ppm	ND - 1220	1600	NA	13000
Nitrite	ppm	NA	75	NA	470
Phosphate, Ortho	ppm	NA	ND	NA	14
Phosphate, Total	ppm	NA	3.1	NA	2100
Sulfate	ppm	NA	736	NA	6950
Sulfide	ppm	NA	ND	NA	ND
TKN-N	ppm	NA	ND	NA	16700
RADIONUCLIDES					
Americium -241	pCi/l	NA	5.5	NA	ND
Americium -241	pCi/g	NA	NA	NA	NA
Plutonium -239	pCi/l	NA	0.4	NA	5.1
Plutonium -239	pCi/g	NA	NA	NA	NA
Uranium -234	pCi/l	NA	780	NA	70
Uranium -234	pCi/g	NA	NA	NA	NA
Uranium -235	pCi/l	NA	36	NA	2.5
Uranium -235	pCi/g	NA	NA	NA	NA
Uranium -238	pCi/l	NA	900	NA	75
Uranium -238	pCi/g	NA	NA	NA	NA

TABLE 2.9

SOLAR EVAPORATION POND 207B (CENTER)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207B (Center) Liquid		207B (Center) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Uranium	pCi/l	NA	ND	NA	ND
Tritium	pCi/l	NA	NA	NA	NA
Tritium	pCi/g	NA	NA	NA	NA
Gross Alpha	pCi/l	4 - 2500	2400	NA	120
Gross Beta	pCi/l	8 - 1500	3900	NA	380
MISCELLANEOUS TESTS					
Alkalinity, Total	ppm	NA	1000	NA	2700
Conductivity @ 25C	uMHOs	NA	1350	NA	3700
Total Dissolved Solids	ppm	NA	13000	NA	ND
Total Organic Carbon	ppm	NA	126	NA	22000
Total Suspended Solids	%	NA	15	NA	10
pH	ppm	7.3-11.3	9.1	NA	9.2
METALS					
Aluminum	ppm	ND - 2.00	ND	NA	2350
Antimony	ppm	ND	ND	NA	ND
Arsenic	ppm	ND	0.014	NA	ND
Barium	ppm	ND	ND	NA	ND
Beryllium	ppm	ND	ND	NA	ND
Bismuth	ppm	ND	ND	NA	ND
Boron	ppm	0.071 - 0.67	2.77	NA	ND
Cadmium	ppm	ND-0.01	ND	NA	108
Calcium	ppm	2.9- 95	22.6	NA	108000
Cerium	ppm	ND	NA	NA	NA
Cesium	ppm	ND - 0.35	NA	NA	NA
Cobalt	ppm	ND	NA	NA	NA
Chromium, Total	ppm	ND	0.094	NA	127

TABLE 2.9

**SOLAR EVAPORATION POND 207B (CENTER)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS**
(continued)

Compound	Units	207B (Center) Liquid		207B (Center) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Chromium, Hexavalent	ppm	NA	NA	NA	97
Copper	ppm	ND - 0.037	0.035	NA	96
Germanium	ppm	ND	NA	NA	NA
Iron	ppm	ND - 0.2	ND	NA	2650
Lead	ppm	ND - 0.002	ND	NA	13
Lithium	ppm	0.052 - 3.5	2.6	NA	ND
Magnesium	ppm	3.9 - 91	181	NA	13700
Manganese	ppm	ND - 0.022	ND	NA	208
Mercury	ppm	ND	ND	NA	2
Molybdenum	ppm	0.004 - 0.037	ND	NA	ND
Nickel	ppm	ND - 0.016	ND	NA	ND
Niobium	ppm	ND	NA	NA	NA
Phosphorous	ppm	ND - 0.2	NA	NA	NA
Potassium	ppm	30 - 110	729	NA	ND
Rubidium	ppm	ND	NA	NA	NA
Selenium	ppm	ND - 0.019	ND	NA	ND
Silicon	ppm	1.4 - 5.5	1.41	NA	2690
Silver	ppm	ND - 0.015	ND	NA	ND
Sodium	ppm	67 - 800	2440	NA	31300
Strontium	ppm	0.14 - 0.52	2.13	NA	848
Tantalum	ppm	ND	NA	NA	NA
Tellurium	ppm	ND	NA	NA	NA
Thallium	ppm	ND	ND	NA	ND
Thorium	ppm	ND	NA	NA	ND
Tin	ppm	ND	0.109	NA	ND
Titanium	ppm	ND	NA	NA	NA

TABLE 2.9

SOLAR EVAPORATION POND 207B (CENTER)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207B (Center) Liquid		207B (Center) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Tungsten	ppm	ND	NA	NA	NA
Vanadium	ppm	ND - 0.0081	NA	NA	NA
Zirconium	ppm	ND - 0.004	NA	NA	NA
Zinc	ppm	ND - 0.041	ND	NA	186
VOLATILE ORGANICS					
Acetone	ppb	NA	ND	NA	ND
Methylene Chloride	ppb	NA	ND	NA	ND
Tetrachloroethene	ppb	NA	ND	NA	ND
SEMIVOLATILE					
Acenaphthene	ppb	NA	ND	NA	ND
Bis(2-ethyl hexyl) phthalate	ppb	NA	ND	NA	ND
4-Chloro-3-methylphenol	ppb	NA	ND	NA	ND
2-Chlorophenol	ppb	NA	ND	NA	ND
1,4-Dichlorobenzene	ppb	NA	ND	NA	ND
2,4-Dinitrotoluene	ppb	NA	ND	NA	ND
Di-n-butyl phthalate	ppb	NA	ND	NA	ND
Fluoranthene	ppb	NA	ND	NA	ND
N-Nitroso-di-propylamine	ppb	NA	ND	NA	ND
Phenol	ppb	NA	ND	NA	ND
Phenols, Total	ppb	NA	NA	NA	NA
Pyrene	ppb	NA	ND	NA	ND
1,2,4-Trichlorobenzene	ppb	NA	ND	NA	ND
PESTICIDES/PCBs					
Atrazine	ppb	NA	9	NA	ND
Diazinon	ppb	NA	ND	NA	ND
Simazine	ppb	NA	ND	NA	ND

TABLE 2.9

**SOLAR EVAPORATION POND 207B (CENTER)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS**
(continued)

References: Rockwell International, 1988a, Solar Evaporation Ponds Closure Plan
Dames and Moore, 1991, A Summary of Chemical Analyses of Sludge and Water

NA -- Not Analyzed
ND -- Not Detected

TABLE 2.10

SOLAR EVAPORATION POND 207B (SOUTH)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

Compound	Units	207B (South) Liquid		207B (South) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
ANIONS					
Ammonia	ppm	NA	0.97	NA	256
Bicarbonate	ppm	NA	ND	NA	ND
Carbonate	ppm	NA	190	NA	ND
Chloride	ppm	NA	745	NA	11300
Cyanide, Total	ppm	NA	0.509	NA	ND
Fluoride	ppm	NA	72.5	NA	ND
Nitrate, N	ppm	NA	1800	NA	11000
Nitrite	ppm	NA	100	NA	860
Phosphate, Ortho	ppm	NA	ND	NA	23
Phosphate, Total	ppm	NA	2.6	NA	260
Sulfate	ppm	NA	784	NA	8530
Sulfide	ppm	NA	1.0	NA	ND
TKN-N	ppm	NA	ND	NA	12100
RADIONUCLIDES					
Americium -241	pCi/l	NA	0.1	NA	2.4
Americium -241	pCi/g	NA	NA	NA	NA
Plutonium -239	pCi/l	NA	0.1	NA	1.9
Plutonium -239	pCi/g	NA	NA	NA	NA
Uranium -234	pCi/l	NA	760	NA	130
Uranium -234	pCi/g	NA	NA	NA	NA
Uranium -235	pCi/l	NA	31	NA	2.9
Uranium -235	pCi/g	NA	NA	NA	NA
Uranium -238	pCi/l	NA	870	NA	150
Uranium -238	pCi/g	NA	NA	NA	NA

TABLE 2.10

SOLAR EVAPORATION POND 207B (SOUTH)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207B (South) Liquid		207B (South) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Uranium	pCi/l	NA	ND	NA	ND
Tritium	pCi/l	NA	NA	NA	NA
Tritium	pCi/g	NA	NA	NA	NA
Gross Alpha	pCi/l	NA	1600	NA	150
Gross Beta	pCi/l	NA	2300	NA	530
MISCELLANEOUS TESTS					
Alkalinity, Total	ppm	NA	860	NA	3000
Conductivity @ 25C	uMHOs	NA	23000	NA	NA
Total Dissolved Solids	ppm	NA	16000	NA	NA
Total Organic Carbon	ppm	NA	297	NA	21000
Total Suspended Solids	%	NA	6.0	NA	NA
pH	units	NA	9.2	NA	NA
METALS					
Aluminum	ppm	NA	ND	NA	1870
Antimony	ppm	NA	ND	NA	ND
Arsenic	ppm	NA	0.0164	NA	ND
Barium	ppm	NA	ND	NA	ND
Beryllium	ppm	NA	NA	NA	NA
Bismuth	ppm	NA	ND	NA	ND
Boron	ppm	NA	2.77	NA	138
Cadmium	ppm	NA	ND	NA	28
Calcium	ppm	NA	18.9	NA	124000
Cerium	ppm	NA	NA	NA	NA
Cesium	ppm	NA	NA	NA	NA
Cobalt	ppm	NA	NA	NA	NA
Chromium, Total	ppm	NA	0.0228	NA	30

TABLE 2.10

SOLAR EVAPORATION POND 207B (SOUTH)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207B (South) Liquid		207B (South) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Chromium, Hexavalent	ppm	NA	NA	NA	NA
Copper	ppm	NA	0.037	NA	95
Germanium	ppm	NA	NA	NA	NA
Iron	ppm	NA	ND	NA	2530
Lead	ppm	NA	ND	NA	9
Lithium	ppm	NA	2.670	NA	ND
Magnesium	ppm	NA	180	NA	9680
Manganese	ppm	NA	0.0182	NA	107
Mercury	ppm	NA	0.001	NA	ND
Molybdenum	ppm	NA	0.122	NA	ND
Nickel	ppm	NA	0.040	NA	ND
Niobium	ppm	NA	NA	NA	NA
Phosphorous	ppm	NA	NA	NA	NA
Potassium	ppm	NA	791	NA	7370
Rubidium	ppm	NA	NA	NA	NA
Selenium	ppm	NA	ND	NA	ND
Silicon	ppm	NA	0.952	NA	4320
Silver	ppm	NA	ND	NA	ND
Sodium	ppm	NA	2940	NA	24200
Strontium	ppm	NA	2.37	NA	720
Tantalum	ppm	NA	NA	NA	NA
Tellurium	ppm	NA	NA	NA	NA
Thallium	ppm	NA	ND	NA	ND
Thorium	ppm	NA	NA	NA	NA
Tin	ppm	NA	ND	NA	ND
Titanium	ppm	NA	NA	NA	NA

TABLE 2.10

SOLAR EVAPORATION POND 207B (SOUTH)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207B (South) Liquid		207B (South) Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Tungsten	ppm	NA	NA	NA	NA
Vanadium	ppm	NA	NA	NA	NA
Zirconium	ppm	NA	NA	NA	NA
Zinc	ppm	NA	0.037	NA	126
VOLATILE ORGANICS					
Acetone	ppb	NA	ND	NA	ND
Methylene Chloride	ppb	NA	ND	NA	ND
Tetrachloroethene	ppb	NA	ND	NA	130
SEMIVOLATILE					
Acenaphthene	ppb	NA	ND	NA	ND
Bis(2-ethyl hexyl)phthalate	ppb	NA	ND	NA	ND
4-Chloro-3-methylphenol	ppb	NA	ND	NA	ND
2-Chlorophenol	ppb	NA	ND	NA	ND
1,4-Dichlorobenzene	ppb	NA	ND	NA	ND
2,4-Dinitrotoluene	ppb	NA	ND	NA	ND
Di-n-butyl phthalate	ppb	NA	ND	NA	ND
Fluoranthene	ppb	NA	ND	NA	ND
N-Nitroso-di-propylamine	ppb	NA	ND	NA	ND
Phenol	ppb	NA	ND	NA	ND
Phenols, Total	ppb	NA	NA	NA	NA
Pyrene	ppb	NA	ND	NA	ND
1,2,4-Trichlorobenzene	ppb	NA	ND	NA	ND
PESTICIDES/PCBs					
Atrazine	ppb	NA	13	NA	ND
Diazinon	ppb	NA	ND	NA	ND
Simazine	ppb	NA	ND	NA	ND

TABLE 2.10

**SOLAR EVAPORATION POND 207B (SOUTH)
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS**
(continued)

References: Rockwell International, 1988a, Solar Evaporation Ponds Closure Plan
Dames and Moore, 1991, A Summary of Chemical Analyses of Sludge and Water

NA -- Not Analyzed
ND -- Not Detected

TABLE 2.11

SOLAR EVAPORATION POND 207C
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS

Compound	Units	207C Liquid		207C Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
ANIONS					
Ammonia	ppm	NA	ND	NA	ND
Bicarbonate	ppm	NA	4000	NA	ND
Carbonate	ppm	NA	25000	NA	ND
Chloride	ppm	NA	18300	NA	5360
Cyanide, Total	ppm	ND-1.9	9650	NA	3200
Fluoride	ppm	NA	ND	NA	22800
Nitrate, N	ppm	0.4-21400	2600	NA	97000
Nitrite	ppm	NA	2500	NA	800
Phosphate, Ortho	ppm	NA	390	NA	ND
Phosphate, Total	ppm	NA	431	NA	1700
Sulfate	ppm	NA	12200	NA	110000
Sulfide	ppm	NA	10	NA	ND
TKN-N	ppm	NA	ND	NA	ND
RADIONUCLIDES					
Americium -241	pCi/l	ND-13000	8.6	NA	1.7
Americium -241	pCi/g	NA	NA	NA	NA
Plutonium -239	pCi/l	210-2100	670	NA	15
Plutonium -239	pCi/g	NA	NA	NA	NA
Uranium -234	pCi/l	NA	2600	NA	5.2
Uranium -234	pCi/g	NA	NA	NA	NA
Uranium -235	pCi/l	NA	120	NA	0.8
Uranium -235	pCi/g	NA	NA	NA	NA
Uranium -238	pCi/l	NA	3900	NA	31
Uranium -238	pCi/g	NA	NA	NA	NA

TABLE 2.11

SOLAR EVAPORATION POND 207C
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207C Liquid		207C Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Uranium	pCi/l	1400-40000	ND	NA	ND
Tritium	pCi/l	ND-6400	ND	NA	NA
Tritium	pCi/g	NA	NA	NA	NA
Gross Alpha	pCi/l	10000-46000	72000	NA	18
Gross Beta	pCi/l	405-44000	170000	NA	420
MISCELLANEOUS TESTS					
Alkalinity, Total	ppm	NA	45000	NA	24000
Conductivity @ 25C	uMHOs	NA	610000	NA	NA
Total Dissolved Solids	ppm	93900-175800	400000	NA	NA
Total Organic Carbon	ppm	NA	54.9	NA	NA
Total Suspended Solids	%	NA	76	NA	NA
pH	ppm	7.7-12.5	10.2	NA	NA
METALS					
Aluminum	ppm	NA	ND	NA	97
Antimony	ppm	NA	ND	NA	ND
Arsenic	ppm	NA	ND	NA	ND
Barium	ppm	NA	ND	NA	ND
Beryllium	ppm	ND-0.6	ND	NA	ND
Bismuth	ppm	NA	ND	NA	ND
Boron	ppm	NA	360	NA	117
Cadmium	ppm	NA	0.312	NA	6
Calcium	ppm	NA	ND	NA	ND
Cerium	ppm	NA	NA	NA	NA
Cesium	ppm	NA	NA	NA	NA
Cobalt	ppm	NA	NA	NA	NA
Chromium, Total	ppm	NA	2.36	NA	18

TABLE 2.11

SOLAR EVAPORATION POND 207C
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207C Liquid		207C Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Chromium, Hexavalent	ppm	NA	NA	NA	NA
Copper	ppm	NA	6.79	NA	6
Germanium	ppm	NA	NA	NA	NA
Iron	ppm	NA	ND	NA	36
Lead	ppm	NA	ND	NA	ND
Lithium	ppm	NA	ND	NA	43
Magnesium	ppm	NA	NA	NA	ND
Manganese	ppm	NA	ND	NA	ND
Mercury	ppm	NA	ND	NA	ND
Molybdenum	ppm	NA	ND	NA	ND
Nickel	ppm	NA	5.09	NA	ND
Niobium	ppm	NA	NA	NA	NA
Phosphorous	ppm	NA	NA	NA	NA
Potassium	ppm	NA	78700	NA	273000
Rubidium	ppm	NA	NA	NA	NA
Selenium	ppm	NA	ND	NA	ND
Silicon	ppm	NA	30.1	NA	422
Silver	ppm	NA	ND	NA	ND
Sodium	ppm	NA	102000	NA	50900
Strontium	ppm	NA	ND	NA	ND
Tantalum	ppm	NA	NA	NA	NA
Tellurium	ppm	NA	NA	NA	NA
Thallium	ppm	NA	ND	NA	ND
Thorium	ppm	NA	NA	NA	NA
Tin	ppm	NA	ND	NA	ND
Titanium	ppm	NA	NA	NA	NA

TABLE 2.11

SOLAR EVAPORATION POND 207C
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

Compound	Units	207C Liquid		207C Sludge	
		1984-1988 Range	1991 Composite	1984-1988 Range	1991 Composite
Tungsten	ppm	NA	NA	NA	NA
Vanadium	ppm	NA	NA	NA	NA
Zirconium	ppm	NA	NA	NA	NA
Zinc	ppm	NA	ND	NA	6
VOLATILE ORGANICS					
Acetone	ppb	NA	43	NA	ND
Methylene Chloride	ppb	NA	ND	NA	ND
Tetrachloroethene	ppb	NA	ND	NA	ND
SEMIVOLATILE					
Acenaphthene	ppb	NA	ND	NA	ND
Bis(2-ethyl hexyl)phthalate	ppb	NA	ND	NA	ND
4-Chloro-3-methylphenol	ppb	NA	ND	NA	ND
2-Chlorophenol	ppb	NA	ND	NA	ND
1,4-Dichlorobenzene	ppb	NA	ND	NA	ND
2,4-Dinitrotoluene	ppb	NA	ND	NA	ND
Di-n-butyl phthalate	ppb	NA	ND	NA	ND
Fluoranthene	ppb	NA	ND	NA	ND
N-Nitroso-di-propylamine	ppb	NA	ND	NA	ND
Phenol	ppb	NA	ND	NA	ND
Phenols, Total	ppb	13-35	NA	NA	NA
Pyrene	ppb	NA	ND	NA	ND
1,2,4-Trichlorobenzene	ppb	NA	ND	NA	ND
PESTICIDES/PCBs					
Atrazine	ppb	NA	ND	NA	ND
Diazinon	ppb	NA	2.8	NA	ND
Simazine	ppb	NA	7.5	NA	ND

TABLE 2.11

SOLAR EVAPORATION POND 207C
SUMMARY OF LIQUID AND SLUDGE SAMPLING RESULTS
(continued)

References: Rockwell International, 1988a, Solar Evaporation Ponds Closure Plan
Dames and Moore, 1991, A Summary of Chemical Analyses of Sludge and Water

NA -- Not Analyzed
ND -- Not Detected

TABLE 2.12

1989 SOIL SAMPLE PARAMETERS LIST

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Cesium
Chromium
Cobalt
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Anions

Nitrate
Nitrate/Nitrite
Sulfide

Radiochemistry

Borings P207889, P207989, P208889, P208989, P209589, P209689, P209789

Americium -241
Cesium -137
Gross Alpha
Gross Beta
Plutonium -239
Radium -226
Radium -228
Strontium -90
Tritium
Total Uranium
Uranium -233, -234
Uranium -235
Uranium -238

Reference: EG&G Rocky Flats, Inc. RFEDs Database

TABLE 2.13

SUMMARY OF 1989 SOIL SAMPLING RESULTS FOR SELECTED METALS AND INORGANICS RANGE OF DETECTION (μg/g)

Borehole Number	Depth (feet)	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper
P207389	3.0-19.3	3760-8840	ND	ND-3.9	48.2-74.5	1.9-2.4	ND	5.4-8.3	7.4-15.2
P207489	0.0-10.0	6490-30400	ND	ND-8.8	40.4-120	1.4-8.7	ND	3.2-81.2	5.3-26.6
P207589	3.0-21.4	7650-11600	ND	ND-17.1	ND-155	2.8-3.2	ND	10.1-11.4	5.8-23.7
P207689	0.0-15.3	7340-8920	ND	ND-4.5	ND-147	2.1-2.7	ND	6.4-7.1	7.0-10.4
P207789	0.0-24.3	6370-10400	ND	ND-5.6	ND-202	1.9-3.0	ND	6.3-8.9	6.3-13.1
P207889	0.0-5.5	7480-32700	ND	2.8-9.9	108-269	2.3-9.1	ND	6.5-28.7	6.1-14.4
P207989	0.0-18.2	7240-11700	ND	ND-7.3	70.1-216	1.9-3.5	ND	7.4-7.7	6.4-35.9
P208889	3.5-15.3	5290-7200	ND	2.6-7.7	59.5-11600	1.5-2.5	ND	5.3-6.1	8.1-15.1
P208989	0.0-14.6	5200-8020	ND	2.6-15.5	76.1-1100	1.5-2.1	ND	5.2-8.8	7.7-12.0
P209089	3.5-17.5	4780-17300	ND	ND-6.8	ND-196	1.4-4.2	ND-60.4	4.6-15	7.3-19.1
P209189	3.0-22.3	4140-15400	ND	2.6-13.6	ND-97.2	2.1-4.5	ND	5.9-14.5	ND-12.0
P209289	0.0-17.8	3240-13200	ND	2.8-6.8	56.3-91	2.6-7.2	ND	7.4-16.3	ND-24.6
P209389	3.0-26.2	2190-12400	ND	ND-5.6	58.2-93	2.5-7.9	ND	4.4-16.1	10.3-14.9
P209489	3.0-21.0	2830-5010	ND	4.3-24.6	ND-76.4	ND-1.7	ND	3.8-6.2	ND-13.8
P209589	0.0-14.5	5360-12900	ND	ND-6.4	ND-97.6	1.4-3.5	ND	4.9-10.4	ND-12.2
P209689	6.2-24.2	9130-8770	ND	ND-12.5	ND-174	2.3-4.1	ND	8.3-10.2	5.9-73.6
P209789	0.0-15.2	5940-7800	ND	ND-2.2	ND-69.4	1.5-2.2	ND	5.6-7.3	ND-8.8
P209889	0.0-15.9	5350-10500	ND	2.5-3.6	45.9-181	1.9-2.9	ND	5.8-9.9	8.7-17.5
P210189	3.0-26.6	6390-23000	ND	ND-3.8	ND-203	ND-1.7	ND	7.6-27.1	ND-24.3
P210289	3.0-19.0	6130-18200	ND	3.1-14.1	ND-254	2.4-5.5	ND	7.2-18.1	7.3-18.0

TABLE 2.13

SUMMARY OF 1989 SOIL SAMPLING RESULTS FOR SELECTED METALS AND INORGANICS RANGE OF DETECTION (µg/g)
(continued)

Borehole Number	Depth (feet)	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper
Upper Tolerance Level* in Background Alluvial Samples		13418	ND	4.3	79.5	4.7	ND	20.0	11.1
Upper Tolerance Level* in Background Bedrock Samples		10428	ND	4.0	121.9	3.4	ND	10.3	16.3

* = Reference: EG&G December 21, 1990, Background Geochemical Characterization Report: Rocky Flats Plant for 1989, Appendix B.
ND = Not Detected above detection limit
NA = Not Analyzed
NC = Upper tolerance level Not Calculated

TABLE 2.13

SUMMARY OF 1989 SOIL SAMPLING RESULTS FOR SELECTED METALS AND INORGANICS RANGE OF DETECTION (μg/g)
(continued)

Borehole Number	Depth (feet)	Lead	Lithium	Mercury	Nickel	Selenium	Silver	Thallium	Zinc	Nitrate/Nitrate (mg/kg)
P207389	3.0-19.3	ND	19.4-23.5	ND	ND-12.5	ND	ND	ND	27.6-46.5	1.1-5.3
P207489	0.0-10.0	ND	18.4-21.7	ND	ND-37.5	ND	ND-5.8	ND	23.3-62.1	1.2-8.3
P207589	3.0-21.4	5.4-24.6	3.7-18.8	0.46-1.1	ND-42.5	ND	ND-2.9	ND	13.7-124	1.6-21
P207689	0.0-15.3	6.9-13.9	5.1-11.8	ND-0.12	ND	ND	ND	ND	ND-10.1	6.3-8.3
P207789	0.0-24.3	10.5-24.7	3.1-13.6	ND-0.18	ND	ND	ND	ND	ND-29.4	3.6-14
P207889	0.0-5.5	4.7-16.7	9.6-23.9	0.12-0.37	ND-41.7	ND	ND-3.1	ND	10.1-45.3	6.4-8.1
P207989	0.0-18.2	6-8.9	6.7-10.1	0.21-0.25	ND-23.0	ND	ND	ND	ND-93.4	2.5-7.6
P208889	3.5-15.3	9.3-20.3	5.6-5.7	ND	ND	ND	ND	ND	29.2-37.9	1900-3400
P208989	0.0-14.6	2.4-27.5	2.3-3.1	ND	ND-21.1	ND	ND	ND	11.2-56.2	1.4-51
P209089	3.5-17.5	8.6-21.7	2.3-35.8	ND-0.24	9.2-35.7	ND	ND	ND	15.8-101	1.6-182
P209189	3.0-22.3	6.4-14.7	2.3-9.2	ND-0.19	9.2-15.8	ND	ND	ND	12.8-35.9	1.6-180
P209289	0.0-17.8	ND-4.9	18.2-23	ND	11.7-33.5	ND	ND-5.3	ND	21.2-90.9	ND-21
P209389	3.0-26.2	ND-3.1	15.8-22.2	ND	ND-28.9	ND	ND-5.6	ND	28.0-59.8	ND-4.0
P209489	3.0-21.0	9.5-14.5	2.2-3.6	ND	ND-11.3	ND	ND	ND	8.4-35.8	4.0-32
P209589	0.0-14.5	10.3-17.6	4.1-9.1	ND	ND	ND	ND	ND	23.5-40.6	560-1300
P209689	6.2-24.2	6.9-30.9	4.3-10.6	ND-0.44	ND-133	ND	ND-3.7	ND	ND-487	2.2-43
P209789	0.0-15.2	3.9-86.9	5.3-8.9	ND-0.32	ND	ND	5.6-7.3	ND	ND	3.2-12
P209889	0.0-15.9	11.1-30.3	4.4-11.8	ND	ND	ND-2.3	ND	ND	29.0-54.8	630-1400
P210189	3.0-26.6	2.6-14	18.6-22.8	ND	ND-21.9	ND-1.3	ND	ND	12.8-82.6	3.4-420
P210289	3.0-19.0	20.2-31.1	4.1-11.9	ND-0.17	ND-10.5	ND	ND	ND	15.5-66.6	1.2-21
Upper Tolerance Level* in Background Alluvial Samples		12.2	ND	NA	21.4	ND	ND	ND	39.7	NC (Mean = 0.8583)

TABLE 2.13

SUMMARY OF 1989 SOIL SAMPLING RESULTS FOR SELECTED METALS AND INORGANICS RANGE OF DETECTION (μg/g)
(continued)

Upper Tolerance Level* in Background Bedrock Samples	18.6	11.6	NA	20.2	ND	ND	ND	62.3	NC (Mean = 0.8953)

* = Reference: EG&G December 21, 1990, Background Geochemical Characterization Report: Rocky Flats Plant for 1989, Appendix B.
ND = Not Detected above detection limit
NA = Not Analyzed
NC = Upper tolerance level Not Calculated

TABLE 2.14

SUMMARY OF 1989 SOIL SAMPLING RESULTS FOR RADIONUCLIDES RANGE OF DETECTION PLUS COUNTING ERROR (pCi/g)

Borehole Number	Depth (feet)	Cesium -137	Gross Alpha	Gross Beta	Plutonium -239	Radium -226	Strontium -90
P207889	0.0-5.5	0(0.01)	0(7)-10(8)	11(5)-13(5)	0(0.01)-0.02(0.02)	0.5(0.1)-0.7(0.1)	-0.6(0.7)- -0.1(0.4)
P207989	0.0-18.2	0(0.01)	12(9)-29(10)	14(5)-28(6)	0(0.01)	0.7(0.1)-1.3(0.1)	-0.4(0.5)- -0.1(0.5)
P208889	3.5-15.3	0(0.01)	17(9)-28(10)	16(5)-29(6)	0(0.01)	0.7(0.1)-1.1(0.1)	-0.4(0.5)-0(0.6)
P208989	0.0-14.6	0(0.01)	24(14)-37(16)	21(6)-30(6)	0(0.01)-0.01(0.01)	0.7(0.1)-1.1(0.1)	-0.2(0.4)-0.1(0.6)
P209589	0.0-14.5	0(0.01)	17(8)-33(11)	22(5)-29(6)	0(0.01)-0.17(0.03)	0.9(0.1)-1.1(0.1)	-0.3(0.7)- -0.2(0.6)
P209689	6.2-24.2	0(0.01)	14(9)-29(10)	23(6)-32(6)	0(0.01)-0.01(0.02)	0.6(0.1)-1.0(0.1)	-0.4(0.6)-0.1(0.6)
P209789	0.0-15.2	0(0.01)	17(9)-25(10)	23(5)-28(6)	0(0.01)-0.03(0.02)	0.6(0.1)-0.9(0.1)	-0.5(0.5)- -0.1(0.4)
Upper Tolerance Level* in Background Alluvial Samples (pCi/g except Tritium pCi/ml)		0.07	38.36	36.82	0.015	0.65	0.73
Upper Tolerance Level* in Background Bedrock Samples (pCi/g except Tritium pCi/ml)		0.07	48.42	34.15	0.021	1.14	0.67

* = Reference: EG&G December 21, 1990, Background Geochemical Characterization Report: Rocky Flats Plant for 1989, Appendix B.
pCi/g = PicoCuries per gram
pCi/ml = PicoCuries per milliliter
NA = Not Analyzed

TABLE 2.14

SUMMARY OF 1989 SOIL SAMPLING RESULTS FOR RADIONUCLIDES RANGE OF DETECTION PLUS COUNTING ERROR (pCi/g)

Borehole Number	Depth (feet)	Tritium (pCi/ml)	Total Uranium	Uranium -233/-234	Uranium -235	Uranium -238
P207889	0.0-5.5	-0.1(0.15)- -0.07(0.15)	0.9-1.3	0.4(0.2)-0.8(0.2)	0(0.1)	0.5(0.1)-0.7(0.2)
P207989	0.0-18.2	-0.08(0.15)-0.79(0.17)	1.2-3.7	0.6(0.2)-1.9(0.4)	0(0.1)-0.1(0.1)	0.6(0.2)-1.7(0.4)
P208889	3.5-15.3	16(1)-36(1)	1.8-2.3	0.7-(0.2)-1.2(0.2)	0(0.1)	1.0(0.2)-1.1(0.2)
P208989	0.0-14.6	0.63(0.15)-0.87(0.16)	1.5-2.0	0.4(0.2)-0.8(0.2)	0(0.1)-0.2(0.1)	0.7(0.2)-1.3(0.3)
P209589	0.0-14.5	5.2(0.2)-12(1)	1.4-2.8	0.7(0.2)-1.4(0.3)	0(0.1)-0.1(0.1)	0.7(0.2)-1.3(0.3)
P209689	6.2-24.2	-0.01(0.14)-2.8(0.2)	0.9-1.5	0.5(0.2)-0.7(0.2)	0(0.1)	0.4(0.1)-0.8(0.2)
P209789	0.0-15.2	-0.15(0.15)-1.5(0.2)	0.8-1.6	0.2(0.2)-0.7(0.2)	0(0.1)-0.1(0.1)	0.5(0.2)-0.9(0.2)
Upper Tolerance Level* in Background Alluvial Samples (pCi/g except Tritium pCi/ml)		0.41	NA	0.66	0.07	0.68
Upper Tolerance Level* in Background Bedrock Samples (pCi/g except Tritium pCi/ml)		0.29	NA	0.98	0.18	1.04

* = Reference: EG&G December 21, 1990, Background Geochemical Characterization Report: Rocky Flats Plant for 1989, Appendix B.
pCi/g = PicoCuries per gram
pCi/ml = PicoCuries per milliliter
NA = Not Analyzed

TABLE 2.15

SUMMARY OF HISTORICAL SOIL SAMPLING RESULTS FOR RADIONUCLIDES RANGE OF DETECTION PLUS COUNTING ERROR (pCi/g)

Borehole Number	Depth (feet)	Gross Alpha	Gross Beta	Plutonium -239	Strontium -90
SP0187	23	10(12)-110(20)	8.6(6.1)-33(7)	-0.03(0.13)-18(1)	-0.3(0.6)-0.2(0.4)
SP0287	13	11(14)-21(9)	7.1(5.6)-36(7)	-0.02(0.13)-0.13(0.15)	0.1(0.4)-0.4(0.3)
SP0387	16	21(14)-22(14)	15(6)-21(7)	-0.01(0.14)-0.05(0.15)	-0.1(0.4)-0.1(0.3)
SP0487	32	11(9)-57(13)	12(6)-31(6)	-0.06(0.07)-0.14(0.11)	-0.2(0.5)-0.6(0.6)
SP0587	26	16(12)-48(12)	13(6)-22(6)	-0.02(0.08)-0.13(0.11)	-0.2(0.7)-0.1(0.7)
SP0687	26	14(8)-39(11)	13(5)-30(6)	-0.02(0.07)-0.52(0.16)	-0.2(1.0)-0.6(0.7)
SP0787	26	11(8)-33(11)	11(5)-26(6)	-0.02(0.09)-2.2(0.3)	-0.2(0.7)-0.6(0.9)
SP0887	9	12(12)-32(11)	14(6)-28(6)	-0.01(0.13)-0.03(0.11)	-0.4(0.7)-0.4(0.7)
SP0987	8	18(10)-25(11)	19(6)-28(6)	-0.05(0.07)-0.02(0.09)	-0.2(0.6)--0.1(0.6)
SP1087	24	16(12)-42(16)	17(6)-29(7)	-0.06(0.10)-3.5(0.3)	-0.6(0.7)-1.1(0.9)
SP1187	29	20(10)-38(11)	19(6)-32(6)	-0.06(0.08)-0.05(0.11)	-0.3(0.8)-0.1(0.6)
SP1287	41	9(12)-39(12)	6.6(5.5)-31(7)	-0.05(0.07)-0.03(0.10)	-0.5(0.6)-0.8(0.8)
SP1387	11	16(12)-36(15)	18(6)-29(7)	-0.06(0.09)-0.05(0.12)	-0.4(0.5)-0.5(0.9)
SP1487	4	26(11)-31(12)	20(6)-23(6)	-0.04(0.08)--0.02(0.09)	-0.1(0.6)-0.1(0.7)
SP1587	17	10(9)-31(10)	10(6)-31(6)	-0.04(0.07)-0.04(0.10)	-0.1(0.6)-0.3(0.7)
SP1687	11	23(13)-59(18)	19(6)-31(7)	-0.05(0.14)-9.0(0.6)	-0.4(0.6)-0.0(0.6)
1886	UD	15(9)-27(10)	22(6)-33(-6)	-0.01(0.01)-0.01(0.02)	NA
2086	UD	28(11)-43(13)	17(6)-36(7)	-0.01(0.02)-0.37(0.06)	NA
2286	UD	23(13)-29(14)	25(6)-40(7)	0.0(0.02)-0.06(0.03)	NA
2586	UD	26(11)-46(16)	19(6)-25(6)	0.01(0.02)-0.42(0.05)	NA
2786	UD	23(11)-68(15)	20(6)-46(7)	-0.01(0.02)	NA
Upper Tolerance Level* in Background Alluvial Samples (pCi/g except Tritium pCi/ml)		38.36	36.82	0.015	0.73

TABLE 2.15

**SUMMARY OF HISTORICAL SOIL SAMPLING RESULTS FOR RADIONUCLIDES
RANGE OF DETECTION PLUS COUNTING ERROR (pCl/g)**
(continued)

Upper Tolerance Level* in Background Bedrock Samples (pCi/g except Tritium pCi/ml)	48.42	34.15	0.021	0.67

* = Reference: EG&G December 21, 1990, Background Geochemical Characterization Report: Rocky Flats Plant for 1989, Appendix B.
NA = Not Analyzed
ND = Not Detected above detection limit
UD = Unknown sample Depth

TABLE 2.15

**SUMMARY OF HISTORICAL SOIL SAMPLING RESULTS FOR RADIONUCLIDES
RANGE OF DETECTION PLUS COUNTING ERROR (pCl/g)**
(continued)

Borehole Number	Depth (feet)	Tritium (pCi/ml)	Uranium -233/-234	Uranium -238	Americium -241
SP0187	23	ND	0.40(0.12)-4(0.6)	0.53(0.13)-2.8(0.5)	0.02(0.06)-2.2(0.2)
SP0287	13	ND	0.26(0.11)-1.5(0.3)	0.19(0.10)-1.2(0.2)	0.01(0.06)-0.22(0.13)
SP0387	16	ND-2(0.3)	0.61(0.18)-0.77(0.18)	0.47(0.17)-0.70(0.18)	0.03(0.07)-0.09(0.12)
SP0487	32	ND-1.3(0.3)	0.52(0.12)-1.6(0.4)	0.66(0.14)-1.3(0.3)	0(0.06)-1.2(0.2)
SP0587	26	ND-3.3(0.3)	0.50(0.13)-1.7(0.2)	0.39(0.11)-1.4(0.2)	0(0.04)-0.13(0.08)
SP0687	26	ND	0.50(0.13)-1.8(0.3)	0.38(0.11)-1.7(0.2)	0.01(0.09)-0.5(0.17)
SP0787	26	ND-2.3(0.3)	0.42(0.11)-1.2(0.2)	0.41(0.11)-1.6(0.2)	-0.06(0.09)-0.61(0.18)
SP0887	9	2.8(0.3)-3.8(0.4)	0.87(0.15)-1.1(0.2)	0.65(0.13)-1.0(0.2)	0.01(0.07)-0.06(0.09)
SP0987	8	ND-0.86(0.28)	0.45(0.12)-0.94(0.18)	0.43(0.11)-1.1(0.2)	0.0(0.06)-0.06(0.08)
SP1087	24	ND-0.65(0.28)	0.45(0.16)-3.7(0.4)	0.58(0.14)-1.4(0.2)	-0.03(0.04)-0.59(0.19)
SP1187	29	ND	0.77(0.21)-1.7(0.2)	0.83(0.21)-1.7(0.2)	-0.04(0.05)-0.02(0.06)
SP1287	41	ND	0.38(0.12)-1.7(0.3)	0.57(0.15)-1.6(0.2)	-0.03(0.04)-0.05(0.06)
SP1387	11	ND	0.66(0.18)-1.7(0.2)	0.93(0.19)-1.5(0.2)	-0.03(0.06)-0.03(0.07)
SP1487	4	ND	0.67(0.14)-0.93(0.17)	0.64(0.14)-1.1(0.2)	-0.06(0.08)-0.03(0.05)
SP1587	17	ND	0.64(0.14)-1.2(0.2)	0.51(0.13)-1.2(0.2)	-0.04(0.09)-0.05(0.10)
SP1687	11	ND	0.49(0.12)-1.1(0.2)	0.55(0.13)-0.78(0.16)	0.0(0.09)-0.96(0.26)
1886	UD	-0.02(0.21)-0.19(0.21)	0.83(0.20)-1.1(0.2)	1.0(0.2)-1.2(0.2)	0(0.01)-0.01(0.02)
2086	UD	0.06(0.21)-3.9(0.3)	0.44(0.15)-1.3(0.2)	1.4(0.3)-2.7(0.3)	0(0.01)-0.30(0.06)
2286	UD	1.7(0.2)-2.0(0.3)	0.71(0.26)-2.0(0.5)	1.2(0.3)-1.8(0.4)	0(0.02)-0.01(0.02)
2586	UD	0.06(0.22)-3.3(0.3)	0.69(0.14)-0.92(0.22)	0.82(0.15)-1.3(0.3)	0(0.01)-0.09(0.04)
2786	UD	1.5(0.2)-11(1)	0.8(0.2)-1.5(0.3)	1.1(0.2)-1.3(0.2)	-0.05(0.06)-0.01(0.02)
Upper Tolerance Level* in Background Alluvial Samples (pCi/g except Tritium pCi/ml)		0.41	0.66	0.68	0.014

TABLE 2.15

SUMMARY OF HISTORICAL SOIL SAMPLING RESULTS FOR RADIONUCLIDES RANGE OF DETECTION PLUS COUNTING ERROR (pCl/g)

(continued)

Upper Tolerance Level* in Background Bedrock Samples (pCi/g except Tritium pCi/ml)	0.29	0.98	1.04	NA

* = Reference: EG&G December 21, 1990, Background Geochemical Characterization Report: Rocky Flats Plant for 1989, Appendix B.
NA = Not Analyzed
ND = Not Detected above detection limit
UD = Unknown sample Depth

Approved By:

8/12/92
Work Plan Manager (Date)

8/13/92
Division Manager (Date)

Effective Date: August 31, 1992

4.0 DATA NEEDS AND DATA QUALITY OBJECTIVES

Phase I RFI/RI Data Quality Objectives (DQOs) have been developed for the collection of field data to supplement the existing, historical data which have been evaluated in Section 2.0 of this Work Plan. The field sampling and analysis program, which is detailed in Section 7.0 of this Work Plan, will strive to augment the available data by generating new information from untested areas within the site boundaries to achieve more uniform coverage of sampling. The program will also generate new types of information with consistent, standardized quality assurance objectives and procedures which increase validity, and establish relative levels of confidence for individual data and the resulting interpretations.

Portions of the historical data set for the Solar Ponds area are of uncertain quality, and apparent discrepancies prevent accurate, meaningful analysis. The proposed field sampling and analysis program will generate a comprehensive set of field observations, field measurements, and laboratory data types. The proposed use of each type of information will dictate the level of data quality required for that measurement.

Site-specific data requirements and related DQOs are summarized in Table 4-1. The data collection activities will focus on the characterization of the source and soils, as required of the Phase I RFI/RI by the IAG. Definition of contamination sources will include surface radiation surveys, vadose zone monitoring and testing of surficial and unconsolidated materials through field measurement, and laboratory analysis. Characterization activities will include geophysical investigations to delineate the Original Pond boundaries and subsurface features such as piping and tanks. The effectiveness of the ITS in capturing shallow ground water will also be evaluated.

The primary objective of an RFI/RI is collection of data necessary to evaluate the nature, distribution, and migration pathways of contaminants and to quantify any risks to human health and the environment. These assessments determine the need for remediation and are used to evaluate remedial alternatives, if necessary. The five general goals of an RFI/RI (U.S. EPA, 1988a) are as follows:

1. Characterize site physical features
2. Define contaminant sources
3. Determine the nature and extent of contamination
4. Describe contaminant fate and transport
5. Provide a baseline risk assessment

However, in accordance with the IAG, the RFI/RI for OU4 has been divided into two phases. Phase I of the RFI/RI will address characterization of the site physical features and definition of contaminant sources. Phase II of the RFI/RI will address determination of the nature and extent of contamination and evaluation of the fate and transport of contaminants at OU4.

Data quality objectives (DQOs) are qualitative and quantitative statements that specify the quality and quantity of data required to support the objectives of the RFI/RI (U.S. EPA, 1987). The DQO process is divided into three stages:

Stage 1 - Identify decision types
Stage 2 - Identify data uses/needs
Stage 3 - Design data collection program

Through application of the DQO process, site-specific goals were established for the Phase I RFI/RI and data needs were identified for achieving those goals. This section of the RFI/RI Work Plan proceeds through the DQO process specific to the Phase I RFI/RI for OU4.

Data collected during previous investigations have been useful in developing and focusing the DQOs. Previous data collection activities focused on site characterization rather than performing a quantitative risk assessment or environmental evaluation. The historical data, along with the OU4 conceptual model, were summarized in Section 2.0 of this Work Plan. This section presents the rationale used in identifying OU4 data needs.

4.1 STAGE 1 - IDENTIFY DECISION TYPES

Stage 1 of the DQO process identifies decision makers, data users, and the types of decisions that will be made as part of the Phase I RFI/RI. The general decision types were identified early in Stage 1 to determine data types sufficient to support decisions.

4.1.1 Identify and Involve Data Users

Data users are divided into three groups: decision makers, primary data users, and secondary data users. The decision makers for OU4 are personnel from EG&G, DOE, EPA, and CDH who are responsible for decisions related to management, regulation, investigation, and remediation of OU4. The decision makers are involved through the review and approval process specified in the IAG. Primary data users are individuals involved in ongoing Phase I RFI/RI activities for OU4. These individuals are the technical staff of CDH, EPA, EG&G, and EG&G subcontractors, including geoscientists, statisticians, risk assessors, engineers, and health and safety personnel. They will be involved in collection and analysis of data and in preparation of the Phase I RFI/RI report, including the Baseline Human Health Risk Assessment and the Environmental Evaluation. Secondary data users are those users who rely on RFI/RI outputs to support their activities. Secondary data users of the Phase I RFI/RI information may include personnel from EPA, CDH, EG&G, and EG&G subcontractors working in areas such as data base management, quality assurance, records control, and laboratory management.

4.1.2 Evaluate Available Data

The historical and recently conducted investigations at the Solar Ponds and associated areas of OU4 have generated a significant quantity of data that is described in Section 2.0 of this Work Plan. The following is a brief discussion of the completeness and usability of existing data based on the information presented in Section 2.0.

4.1.2.1 Quality and Usability of Analytical Data

Analytical data used in characterizing contamination at OU4 are in the process of being validated in accordance with EM Program QA procedures. As of early 1991, only a small fraction of the data has been validated. At present much of the analytical data for radionuclides have been rejected. Data were rejected because (1) sampling/analytical protocol did not conform to significant aspects of the QA/QC Plan (Rockwell International, 1989a) or (2) there is insufficient documentation to demonstrate conformance with these procedures. These data, at best, can be considered only qualitative measures of the analyte concentrations. Analytical data generated during the 1991 sampling and analysis of Solar Pond liquids and sludges is of significantly better quality than previous Solar Pond data (Weston, 1991).

The analytical data have been used qualitatively to scope the Phase I RFI/RI activities at OU4 as presented in this Work Plan. Valid data are needed to accurately evaluate contamination at OU4. Additionally, data obtained periodically are needed to perform statistical evaluations of ground water quality and to assess temporal trends.

Presently, under the site-wide RCRA ground water monitoring program, ground water quality at OU4 is compared to sitewide definitions of background ground water quality to evaluate contamination. The methods used to establish background chemical quality at the RFP are presented in the Final Background Geochemical Characterization Report for 1989, Rocky Flats Plant (EG&G, 1990d).

4.1.2.2 Physical Setting

The physical setting of the Solar Ponds area is described in detail in Section 2.0. Additional data are needed for consistency and to provide more thorough coverage of the site.

4.1.2.3 Characterization of Contamination of the Solar Ponds

The nature of contamination is described in detail in Section 2.5. Weston has thoroughly characterized the pond liquids and sludges and no further data are needed. However, additional data for the soils are needed to fully characterize the site.

4.1.3 Develop Conceptual Model

A conceptual model for OU4 has been developed in Section 2.6 and is illustrated in Figure 2-30. This model includes a description of contaminant sources, release mechanisms, transport medium, contaminant migration pathways, exposure routes, and receptors. Because few previous studies have provided valid data, the model is a basic Phase I model. The site-specific conceptual model for OU4 is discussed briefly below.

The primary source of contamination at the Solar Ponds are the liquids and sludges contained in the ponds. Secondary sources of contamination may include lining materials and base course materials; soils beneath the Solar Ponds that have been contaminated by pond liner and/or pipeline leakage; ground water, contaminated surface water, and contaminated surface soils as a result of aerosol dispersion from the ponds.

The primary release mechanisms for contaminants from the Solar Ponds are likely to be pond liner leakage, pipeline leakage and windblown aerosols. The exposure pathways for contaminants from the Solar Ponds to reach receptors are via ingestion, inhalation, or dermal contact to windblown contaminated soil, contaminated ground water, and surface water. Receptors are defined as the human or ecological populations exposed to contaminants at the exposure points. Human receptors include primarily present and future RFP workers and secondarily residents living downwind and/or downgradient of OU4. Ecological receptors include terrestrial wildlife, aquatic wildlife, and terrestrial and aquatic vegetation in and around OU4.

4.1.4 Specify Phase I RFI/RI Objectives and Data Needs

Based on the existing site information (Sections 2.2 through 2.4), the nature of contamination (Section 2.5), the site-specific conceptual model for OU4 (Section 2.6), and an evaluation of the quality and usability of the existing data (Section 4.1.2), site-specific Phase I RFI/RI objectives/data needs associated with identifying contaminant sources and characterizing contamination have been developed. These are summarized in Table 4.1 and are discussed below.

In accordance with the IAG, the specific objectives of the Phase I RFI/RI field investigation for OU4 are as follows:

Characterize Site Physical Features and Define Contaminant Sources

- Determine the boundaries of the Original Pond.

- Assess the Interceptor Trench System
  - Determine the extent at which the ITS is keyed into bedrock
  - Determine the head differential across the ITS

- Delineate sandstone paleochannels/fracture sets in bedrock

- Investigate presence of subsurface piping

- Determine the presence or absence of contamination in surficial soils

- Determine the presence or absence of contamination in subsurface/vadose zone materials.

As previously discussed in Sections 2.3 and 2.5, extensive analysis of pond liquids and sludges have already been conducted in order to characterize the chemical, radiochemical and geochemical characteristics of the material contained in each pond. Historical results and the May 1991 sampling and analysis by R. F. Weston are deemed sufficient to characterize the Solar Ponds' liquids and sludges. Therefore, further sampling and analysis is not proposed.

Provide a Baseline Risk Assessment

The objectives of the Baseline Risk Assessment are discussed in Sections 8.0 and 9.0.

Determine Nature and Extent of Contamination

This will be addressed in the Phase II RFI/RI Work Plan.

Describe Contaminant Fate and Transport

This will be addressed during Phase II RFI/RI Work Plan.

4.2 STAGE 2 - IDENTIFY DATA USES/NEEDS

The data needed to meet each of the site-specific Phase I RFI/RI objectives developed for OU4 are listed in Table 4-1. The associated sampling and analysis activities are also identified in Table 4-1. Specific plans for obtaining the needed data are presented in Section 7.0 (Field Sampling Plan). The following sections discuss the uses, general types, quality, and quantity of the data needed for the OU4 Phase I RFI/RI.

4.2.1 Identify Data Uses

RFI/CMS data can be categorized according to use for the following general purposes:

- Site characterization
- Health and safety
- Risk assessment
- Evaluation of alternatives
- Engineering design of alternatives
- Monitoring during remedial action
- Determination of potentially responsible parties (PRPs)

Because this Work Plan describes a Phase I RFI/RI, data uses such as engineering design and monitoring during remediation (both remedial action activities) will not be considered. The data use for PRP determination is also not appropriate to this Work Plan. The remaining four data uses will be important in meeting the objectives identified in Section 4.1.4. Data uses for specific sampling and analysis activities for the Phase I investigation at OU4 are listed in Table 4-1.

4.2.2 Identify Data Types

Data types can be initially divided into broad groups and again divided into more specific components. Examples of data types include geophysical data, physical data, chemical data, water level data, and field screening data.

For the Phase I investigation, surficial soil and subsurface unconsolidated material samples will be collected. Radiation surveys will be conducted over the Solar Ponds area and geophysical surveys will be conducted in the areas of the Original Pond, the Solar Ponds and the ITS. Vadose zone monitoring and water level determination at the ITS will also be conducted. These data types will provide Phase I information to further characterize physical features and contamination at OU4. Selection of chemical analyses has been based on the objectives of the Phase I program and on the past activities at the units. Data types are listed in Table 4-1.

4.2.3 Identify Data Quality Needs

EPA defines five levels of analytical data, listed as follows (U.S. EPA, 1987):

- Level I - Field screening or analysis using portable instruments. Results are often not compound-specific and not quantitative, but results are available in real time. It is the least costly of the analytical options.

- Level II - Field analysis using more sophisticated portable analytical instruments; in some cases, the instruments may be set up in a portable laboratory onsite. There is a wide range in the quality of the data that can be generated. The quality depends on the use of suitable calibration standards, reference materials, and sample preparation equipment and on the training of the operator. Results are available in real time or several hours.

- Level III - All analysis performed in an offsite laboratory. Level III analyses may or may not be performed according to CLP procedures, but the validation or documentation procedures required of CLP Level IV analysis are not usually utilized. The laboratory may or may not be a CLP laboratory.

- Level IV - CLP routine analytical services (RAS). All analyses are performed in an offsite CLP analytical laboratory following CLP protocols. Level IV is characterized by rigorous QA/QC protocols and documentation.

- Level V - Analysis by non-standard methods. All analyses are performed in an offsite analytical laboratory that may or may not be a CLP laboratory. Method development or method modification may be required for specific constituents or detection limits. CLP special analytical services (SAS) are Level V.

All five levels of data quality will be necessary for performing Phase I field activities. The levels appropriate to the data need and data use have been specified in Table 4-1.

Data quality for the Phase I RFI/RI will be achieved by meeting the requirements for Level I through V data outlined in GRRASP (EG&G, 1991j) and by adhering to the data collection protocols provided in agency-approved Standard Operating Procedures (SOPs) and Procedure Change Notices (PCNs).

4.2.4 Identify Data Quantity Needs

Data quantity needs are based primarily on an evaluation of the information available for characterizing the site physical features and contamination at OU4. This is consistent with guidance provided in Data Quality Objectives for Remedial Response Activities (U.S. EPA, 1987) and Guidance for Data Useability in Risk Assessments (U.S. EPA, 1990). Additionally, data quantity needs are designed to be consistent with similar data collection activities performed for the Phase I RFI/RI for OU 6 (Walnut Creek) and OU 9 (Original Process Waste Lines). The rationale for sampling quantities is described in the FSP presented in Section 7.0 of this Work Plan.

To ensure that a sufficient amount of valid data are generated, the FSP was designed to include (1) a rationale for all field activities based on an evaluation of the existing information, (2) a phased approached using screening-level techniques to identify and/or locate critical sampling sites, and (3) contingency plans for obtaining data from critical locations. These components of the FSP are discussed further in Section 7.0.

4.2.5 Evaluate Sampling/Analysis Options

To ensure that sufficient and adequate data are collected, the Phase I RFI/RI for OU4 is based on a stepped, or phased, approach in which field screening techniques (e.g., Level I and II data types) are used to direct data collection activities designed to obtain Level III through V data. This stepped program has been designed to be consistent with the IAG schedule.

This approach maximizes collection of useful data because field screening techniques are used to properly locate and minimize intrusive data collection activities such as borehole drilling. Additionally, this approach minimizes the volume of hazardous waste material generated that requires special management, the potential exposure of field personnel to hazardous waste material, and the overall time to perform the field activities.

Three types of activities will be performed during the Phase I field investigation: (1) screening activities, (2) sampling activities, and (3) monitoring well installation. Screening activities (Levels I and II) include visual inspection, radiological surveys, and geophysical techniques. Analysis of surficial soils and subsurface materials from test borings, will provide Level III through IV data. Monitoring wells will provide Level I type data.

Sampling options for the Phase I RFI/RI were selected on the basis of their ability to (1) obtain data consistent with the DQOs in the least intrusive manner, (2) obtain multiple types of data at each sampling location, and (3) reduce the number of "leave-behind" sampling locations requiring long-term maintenance and care.

4.2.6 Review of PARCC Parameter Information

PARCC parameters are indicators of data quality. Precision, accuracy, and completeness goals are established for this Work Plan according to the analyses being performed and the analytical levels.

PARCC goals are specified in the Quality Assurance Addendum (QAA) discussed in Section 10.0 of this Work Plan.

The analytical program requirements for OU4 are discussed in Section 7.4 of this Work Plan. The GRRASP (EG&G, 1991j) and the RFP site-wide Quality Assurance Project Plan (QAPjP) provide listings of the CLP analytes and detection/quantification limits for Target Compound List (TCL) volatile organics, semivolatile organics, pesticides/PCBs, Target Analyte List (TAL) metals, radionuclides, and inorganic parameters. These analytical methods are appropriate for meeting the data quality requirements for analytical Levels I through V during the Phase I RFI/RI. The precision, accuracy, and completeness parameters for analytical Levels I through V are discussed below, along with the completeness and representativeness for all analytical levels.

Precision measures the reproducibility of measurements under a given set of conditions. Accuracy measures the bias or source of error in a group of measurements. Precision and accuracy objectives for the analytical data collected for the Phase I RFI/RI at OU4 will be evaluated according to the control limits specified in the referenced analytical method and/or in data validation guidelines. For the radionuclide analyses, the accuracy objectives specified in the GRRASP the RFP site-wide QAPjP will be followed. The specified criteria for precision and accuracy are described in the QAA. Precision and accuracy for non-analytical data will be achieved through protocols outlined in agency-approved SOPs and PCNs.

Completeness is defined as the percentage of measurements made that are judged to be valid. The target completeness objective for the OU4 field and analytical data is 100 percent, although 90 percent will be the minimum acceptable level. The FSP was designed to generate a sufficient amount of valid data and to include (1) a rationale for all field activities based on an evaluation of the existing information, and (2) a phased approach using screening level techniques to identify and/or locate critical sampling sites. These components of the FSP are discussed further in Section 7.0.

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared to another. In order to achieve comparability, work will be performed at OU4 in accordance with approved sampling and analysis plans, standard analytical protocols, and approved SOPs for data collection. Consistent units of measurement will be used for data reporting.

Representativeness expresses the degree to which sample data accurately and precisely represent the characteristics of a particular site or condition. Representativeness is a qualitative parameter related to the design of the sampling and analysis components of the investigative program. The FSP described in Section 7.0 of this Work Plan and the referenced SOPs describe the rationale for the sampling program to provide for representative samples.

4.3 STAGE 3 - DESIGN DATA COLLECTION PROGRAM

The purpose of Stage 3 of the DQO process is to design the specific data collection program for the Phase I RFI/RI for OU4. To accomplish this, the elements identified in Stages 1 and 2 are assembled and the Sampling and Analysis Plan (SAP) prepared. The SAP consists of (1) a Quality Assurance Project Plan (QAPjP) that describes the policy, organization, functional activities, and QA/QC protocols necessary to achieve the DQOs dictated by the intended use of the data and (2) a FSP that provides guidance for all fieldwork by defining in detail the sampling and data collection methods to be used in the Phase I RFI/RI for OU4. These two components are presented in Sections 7.0 and 10.0 of this Work Plan. A detailed discussion of all samples to be obtained is presented in Section 7.0 for each media and includes sample type, number of samples, sample location, analytical methods, and QA/QC samples.

TABLE 4.1
PHASE I RFI/RI DATA QUALITY OBJECTIVES FOR OU4

Objective (Data Need)	Data Type	Sampling/Analysis Activity	Analytical Level	Data Use
1) Determine the boundaries of the Original Pond.	Facility drawings, aerial photographs, construction reports	Review facility engineering drawings, aerial photos, and reports.	NA	Site characterization Evaluation of remedial alternatives Baseline risk assessment Environmental evaluation
	Geophysical data	Conduct GPR survey in vicinity of original pond.	I	
		Process and analyze data.		
		Conduct follow-up GPR survey as needed.		
	Chemical/physical data of soil/fill	Collect soil/fill core samples along depth profiles, analyze for full-suite.	IV (V for radiological analyses)	
2) Assess the Interceptor Trench System (ITS). a) Determine the extent at which the ITS is keyed into bedrock. b) Determine the head differential across the ITS.	Facility Drawings, As-Built Drawings	Review facility engineering drawings and reports.	NA	Site characterization Evaluation of remedial alternatives
	Water level data	Install piezometers across the ITS and obtain monthly water level measurements.	I	
3) Delineate sandstone paleo-channel	Physical data of bedrock	Review existing geologic data.	N/A	Site characterization, define potential pathway of contaminant migration
		Collect soil core samples and analyze/log cores.	I	

TABLE 4.1
PHASE I RFI/RI DATA QUALITY OBJECTIVES FOR OU4
(continued)

Objective (Data Need)	Data Type	Sampling/Analysis Activity	Analytical Level	Data Use
4) Investigate presence of sub-surface piping	Geophysical Data OPWL records	Conduct GPR survey in vicinity of Original Pond and Existing Ponds	I	Site characterization
		Process and analyze data	I	
		Conduct follow-up GPR as need-ed	I	
5) Determine the presence or absence of contamination in surface soils.	Radiological data Chemical data Physical data	Conduct radiological survey.	II	Site characterization Baseline risk assessment Environmental evaluation Evaluation of remedial alternatives
		Collect surficial soil scrapes; analyze for selected parameters (see Table 7.5)	IV (V for radiological analyses	
6) Determine the presence or absence of contamination in subsurface/unconsolidated materials.	Radiological data Chemical data Physical data	Collect soil samples along depth profiles, analyze for selected parameters dependent on location of borehole.	IV (V for radiological analyses	Site characterization Baseline risk assessment Environmental evaluation Evaluation of remedial alternatives
7) Characterize vadose zone migration pathways	Physical data Chemical data	Test applicability of vadose zone monitoring techniques, including neutron logging, tensiometer, and suction lysimeter measurements.	II, III	Site characterization and post-closure monitoring

Approved By:

8/12/92
Work Plan Manager (Date)

8/13/92
Division Manager (Date)

Effective Date: August 31, 1992

5.0 RCRA FACILITY INVESTIGATION/REMEDIAL INVESTIGATION TASKS

5.1 TASK 1 - PROJECT PLANNING

Project planning for the implementation of the Phase I RFI/RI for OU4 will include numerous activities in addition to tasks completed as part of this Work Plan. Review of previous site investigations, preliminary site characterization, preliminary identification of potential ARARs and the development of Data Quality Objectives and a FSP have all been completed as part of this Work Plan and are contained in Sections 2.0, 3.0, 4.0, and 7.0.

Prior to performing field activities for OU4, it will be necessary to review new information and data that become available after preparation of this Work Plan. Additional planning will be required to; 1) coordinate with other field investigation programs occurring in the same vicinity and ongoing operations at the Solar Ponds (i.e., pond dewatering and sludge removal), 2) accommodate the special requirements of security within the Protected Area (PA) and 3) evaluate and plan for health and safety concerns.

The schedule and completion of field activities will be contingent on the clean out of the individual ponds. The schedule as to when individual ponds will be cleaned and available for field investigative activities is uncertain. Therefore, flexibility has been incorporated into the Field Sampling Plan (Section 7.0). Other nearby OU field programs such as OU6, Walnut Creek Drainage, and of particular note, OU9, Original Process Waste Lines (OPWL) will be generating analytical and site characterization data.

The OPWL network resides extensively within the boundaries of the Solar Ponds area and represent significant potential sources of contamination which will be investigated as a separate OU. However, planning of these activities should be closely coordinated with OU4 activities to prevent redundancy and to optimize efficiency.

Security requirements of working within the PA will require detailed planning and coordinating with RFP personnel. The use of pickup trucks and other vehicles will likely be constrained. It is anticipated that health and safety requirements, such as level of personnel protective equipment, will be dependent on the areas within OU4 and other ongoing activities. Daily coordination and scheduling with ongoing activities will need to be conducted to ensure proper health and safety measures.

5.2 TASK 2 - COMMUNITY RELATIONS

In accordance with the IAG, the RFP is developing a Community Relations Plan (CRP) to inform and actively involve the public in decision-making as it relates to environmental restoration activities. The vehicle for public involvement in the RFI/RI process is through the Technical Review Group process. The CRP will address the needs and concerns of the surrounding communities as identified through approximately 80 interviews with federal, state, and local elected officials; businesses; medical professionals; educational representatives; interest groups; media; and residents adjacent to the RFP.

A Draft CRP was issued for public comments in January 1991. The Draft CRP was revised to reflect public comment, and following EPA and CDH approval, a final CRP was scheduled to be released in August 1991. Accordingly, a site-specific CRP is not required for OU4.

Current community relations activities concerning environmental restoration include participation by plant representatives in informational workshops; presentations at meetings of the Rocky Flats Environmental Monitoring Council; briefings for citizens, businesses, and surrounding communities on environmental restoration and monitoring activities; and public comment opportunities on various EM Program plans and actions. RFP personnel involve several special interest groups in decisions that pertain to environmental restoration activities, including the Rocky Flats Cleanup Commission, the recipient of the EPA Technical Assistant Grant.

In addition, a Speakers' Bureau program provides plant speakers to civic groups and educational organizations, and a public tours program allows the public to visit the RFP. The RFP also produces fact sheets and periodic updates on environmental restoration activities for public information and responds to numerous public inquiries regarding the RFP.

5.3 TASK 3 - FIELD INVESTIGATION

The Phase I RFI/RI field investigation for the Solar Ponds area is designed to meet the objectives outlined in Section 4.0 of this Work Plan. Additionally, the data will be used to support the Phase I Environmental Evaluation and the Phase I Human Health Risk Assessment.

Several types of activities will be performed during the Phase I field investigation including screening activities and sampling activities. Screening activities include radiological surveys, geophysical investigations, visual inspections, piezometer installation and bedrock borehole installation. Technical details regarding these activities are discussed in Section 7.0. Sampling activities include surficial soil sampling, subsurface sampling using vadose zone borings.

5.3.1 Site-Wide Radiological Survey and Surficial Sampling Program

- Alpha and gamma/beta radiation readings will be taken at nearly 350 locations throughout the Solar Ponds area. Real-time radiation readings will be used to assess surficial radiation in the Solar Ponds area, transported by aerosol dispersion or as seeps to the surface. Readings will be taken at each node of a 100-foot by 100-foot grid in the ITS area, and at nodes of a more dense grid in the Solar Ponds area as shown on Figure 7-2.

- A 1/4 inch by 2 inches wide and 2 3/4 inches long surficial soil sample will be collected at hot spots identified during the radiological survey. Areas exhibiting a high count level of more than 250 cpm on the Ludlum 12-1A will be considered for surficial sampling.

- A composite surficial soil sample will be collected at randomly selected locations within the grid system described above. Samples will be collected at a ratio of 1 in 14 survey points (approximately 25 samples) and analyzed for metals, inorganics and radionuclides.

5.3.2 Vadose Zone Monitoring

- Research on available vadose zone monitoring techniques will be conducted and their applicability to the Solar Ponds area assessed.

- Instrumentation such as lysimeters, tensiometers or other techniques will be utilized for potential use at the Solar Ponds area.

5.3.3 Original Pond Investigation

- Available documentation regarding the Original Pond will be obtained and reviewed possibly including original construction drawings, aerial photographs before, during, and after 1952 to 1970, and any other available historical documentation.

- The surface radiation survey and surficial soil sampling program described in Section 5.3.2 above includes the Original Pond area.

- A surface geophysical investigation using ground penetrating radar (GPR) will be performed to delineate boundary of Original Pond and to locate subsurface features such as piping and tanks. The results will be coordinated with the OPWL investigation.

- Borehole construction and soil sample analysis will be conducted at four locations in the Original Pond area as shown on Figure 7-2. Three boreholes will be placed within the perimeter of the old pond, and one will be placed on the perimeter of the Original Pond.

- A 0 to 1-inch sample will be collected at each borehole to provide data comparable to the surficial soil program. A minimum of five-foot intervals will be collected thereafter. Downhole geophysical investigations will be conducted at each borehole. Samples will be analyzed for metals, inorganics, radionuclides, volatile and semivolatile organic compounds, pesticides, and nitrate.

5.3.4 Solar Ponds Area

- Any recently obtained data in the vicinity of the Solar Ponds will be reviewed such as monthly surface water monitoring results and quarterly ground water monitoring results. Any additional data generated as a result of pond liquid and sludge removal operations will also be obtained and reviewed.

- Surface radiation survey and surficial soil sampling program described in Section 5.3.2 includes the Solar Ponds area.

- A surface geophysical investigation using GPR will be performed to identify subsurface features such as piping or tanks. The results will be coordinated with the OPWL investigation.

- A visual survey of pond liner damage will be conducted and locations of liner cracks or damage placed on a map.

- Borehole construction and soil sample analysis will be conducted at 17 locations inside the ponds, and 9 locations on or near pond embankments as shown on Figure 7-3. Borings inside the ponds will be placed in cracks identified in the visual survey to determine if the cracks provided the primary pathways for contaminant migration. Borings inside the ponds will also be placed in areas where the current liner is in good condition to determine if cracks in the old liners provided pathways for contaminant migration as well. The liner and base course will be removed at the borehole, and undisturbed materials below sampled. A 0 to 1-inch sample and 5-foot minimum samples thereafter will be collected. Perimeter boreholes are intended to assess lateral migration of pond contaminants, and will be sampled at the same intervals as borings inside the ponds. Proposed analyses include those listed for the Original Pond soil samples.

5.3.5 Interceptor Trench System and Remainder of Site

- Available documentation will be reviewed and personnel interviews conducted regarding the ITS design and construction.

- The surface radiation survey and surficial soil sampling program described in Section 5.3.2 includes the ITS and remainder of site.

- Borehole construction and soil sample analysis will be conducted at 19 locations in the ITS, and on the outer edges of the Solar Ponds area. Six of these borings will be advanced to bedrock to delineate the Arapahoe Sandstone as shown in green on Figure 7-4. Sampling intervals are consistent with those described above. The analytical parameter list includes metals, nitrate, inorganics, and radionuclides.

- A series of piezometers will be installed in three locations across the primary french drain and in two finger drains to provide hydrologic characterization information. Water levels will be obtained and used to assess system effectiveness. Once installed and preliminary effectiveness evaluated, tracer studies may be proposed to investigate potential contaminated flow paths.

5.4 TASK 4 - SAMPLE ANALYSIS AND DATA VALIDATION

Analytical procedures will be completed in accordance with the ER Program QAPjP (EG&G, 1991k). Analytical detection limits, sample container and volume requirements, preservation requirements, and sample holding times are discussed in Section 7.4 of the FSP.

Results of data review and validation activities will be documented in data validation reports. EPA data validation functional guidelines will be used for validating organic and inorganic (metals) data (U.S. EPA, 1988c). Data validation methods for radiochemistry and major ions data have not been published by EPA, but data and documentation requirements have been developed by EM Program QA staff. Data validation methods for these data are derived from these requirements. Details of the data validation process are described in the QAPP (EG&G, 1991k).

Phase I data will be reviewed and validated according to data validation guidelines in the QAPjP and the Data Validation Functional Guidelines (EG&G, 1990b). These documents state that the results of data review and validation activities will be documented in data validation reports.

5.5 TASK 5 - DATA EVALUATION

Data collected during the Phase I RFI/RI, as well as previously collected data, will be incorporated into the existing RFEDS database and will be used to better characterize contaminant sources and soil. These results also will be used in delineating the requirements for the Phase II RFI/RI plans for determining the impact of OU4 on surface water, ground water, air, the environment, and biota, as well as the potential contaminant migration pathways at OU4. Additionally, data will be used to support the evaluation of proposed remedial alternatives and the BRA.

5.5.1 Site Characterization

The additional data collected during Phase I will be incorporated into the existing site characterization. Geophysical data will be used in the delineation of the Original Pond. Physical and chemical data will be used in the delineation of the Original Pond and to delineate sandstone channels and possible fracturing in the bedrock. The site geologic map and cross sections will be revised on the basis of new information. A bedrock topography map will be produced using all available data. Water level data will be used to characterize the ground water flow regime in the vicinity of the Solar Ponds and to assess the effectiveness of the ITS.

5.5.2 Source and Soils Characterization

Analytical data from unconsolidated material samples and surficial soils will be used to:

- Characterize the nature of source contaminants
- Characterize the lateral and vertical extent of source contaminants
- Evaluate on-site contaminant concentrations
- Quantify the volume of source material.

Analytical data obtained from samples of soils will be used to characterize the sources of contamination. Data will be summarized graphically and/or in tabular form to assist interpretation. If appropriate, contaminant isopleth maps will be prepared to summarize the spatial distribution of source and soil contaminants.

The criteria for the identification of contamination will be analyte-specific for each geologic unit (such as the Rocky Flats Alluvium, Colluvium, or artificial fill). For all analytes (including radionuclides), only those concentrations that exceed the site-specific background concentrations will be considered likely evidence of contamination. These data will be compared to sitewide background values provided in the Final Background Geochemical Characterization Report for 1989, or the most recent version (EG&G, 1990d).

5.6 TASK 6 - PHASE I BASELINE RISK ASSESSMENT

As required by the IAG, a Baseline Risk Assessment (BRA) that will address the risk associated with source and soils will be performed as part of the Phase I RFI/RI report. The BRA includes a Human Health Risk Assessment and an Environmental Evaluation for OU4. The purpose of the Human Health Risk Assessment and Environmental Evaluation are to assess the potential human health and environmental risks associated with the site and to provide a basis for determining whether remedial actions are necessary. In accordance with the IAG, risks will be calculated at the source. The Human Health Risk Assessment will address potential public health risks, and the Environmental Evaluation will address environmental impacts. The overall risk assessmetn plan is included in Section 8.0 of this document, but only the soils pathway will be evaluated during the Phase I investigation.

Existing data and data collected during the Phase I RFI/RI will be used to support the quantitative Human Health Risk Assessment and Environmental Evaluation. The sampling program will be designed to generate data that meet the requirements set forth in Guidance For Data Useability In Risk Assessment (U.S. EPA, 1990).

These assessments will aid in the preliminary screening of site remedies based on the contaminants of concern and the environmental media associated with potential risks to public health and the environment. The risk assessment process will be accomplished in five general steps:

1. Identification of chemicals of concern
2. Exposure assessment
3. Toxicity assessment
4. Risk characterization
5. Qualitative and quantitative uncertainty analysis.

As stated in the IAG, a risk characterization of the following scenarios will be developed:

1. Current site conditions (No Action Alternative)
2. Worker and public exposure during remedial action
3. Past remedy risk.

If the Human Health Risk Assessment and Environmental Evaluation determine that risks posed by contamination at OU4 must be remediated, Tasks 7 and 8 will be conducted.

The objectives and the description of work for the Human Health Risk Assessment are described in detail in Section 8.0 of this Work Plan. The Environmental Evaluation Work Plan is presented in Section 9.0.

5.7 TASK 7 - DEVELOPMENT, SCREENING, AND DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

5.7.1 Remedial Alternatives Development and Screening

This section identifies potential technologies applicable to remediation of contaminated soils, surface water, and ground water within and affected by OU4. The identified technologies are based on the preliminary site characterization developed in Section 2.0. Identification and screening of technologies, assembling an initial screening of alternatives, and identification of interim response actions will be conducted while the Phase I RFI/RI is being conducted. However, investigation of this operable unit is in its early stages; thus, remedial alternatives are only briefly reviewed in this section. A more detailed evaluation of the remedial alternatives for OU4 will be performed as more data are collected.

The process employed to develop and evaluate alternatives for OU4 will follow guidelines provided in the National Contingency Plan (NCP). Although RCRA regulations will direct remedial investigations at OU4, the CERCLA process will also be considered for guidance because it specifies in greatest detail the steps that should be followed for selection of remedial alternatives. In addition, the IAG requires general compliance with both RCRA and CERCLA guidance.

The steps followed to develop remedial alternatives for OU4 are as follows:

1. Develop a list of general types of actions appropriate for OU4 (such as containment, treatment, and/or removal) that may be implemented to satisfy the objectives defined in the previous step. These general types or classes of actions are generally referred to as "general response actions" in EPA guidance.

2. Identify and screen technology groups for each general response action. Screening will eliminate groups that are not technically feasible at the site.

3. Identify and evaluate process options for each technology group to select a process option representing each technology group under consideration. Although specific process options are selected to represent a technology group for alternative development and evaluation, these processes are intended to represent the broader range of options within a general technology group.

4. Assemble the selected representative technologies into site closure and corrective action alternatives for OU4 that represent a range of treatment and containment combinations, as appropriate.

5. Screen the assembled alternatives in terms of the short- and long-term aspects of three broad criteria: effectiveness, implementability, and cost. Because the purpose of the screening evaluation is to reduce the number of alternatives that will undergo thorough and extensive analysis, alternatives will be evaluated in less detail than subsequent evaluations.

6. Develop preliminary cancer risk-based remedial action goals for affected media. Preliminary remedial action goals will be applied as performance objectives for evaluating the effectiveness of specific technology processes identified as candidate components of viable remedial action alternatives. Consistent with the NCP, preliminary remediation goals will be established at a 1×10^{-6} excess cancer risk point of departure evaluated at the source. As the CMS/FS evolves, preliminary remediation goals may be revised to a different risk level on the basis of consideration of appropriate factors that include, but are not limited to, exposure, uncertainty, and technical issues.

7. Remediation goals associated with toxic, non-cancer risk will be determined using the appropriate reference dose for each chemical present on the site. A Hazard Index (HI) will then be calculated. If the HI exceeds 1.0, further investigation of preliminary remediation goals will be evaluated. If the HI is less than 1.0, a toxic risk does not exist at the site and remediation would not be required.

For the Phase I RFI/RI Work Plan, the appropriate level of alternatives analysis is the listing of general response actions most applicable to the type of site under investigation. General response actions are defined as those broad classes of actions that may satisfy the objectives for remediation defined for OU4. Table 5.1 provides a list and description of general response actions and typical technologies associated with remediating soils, ground water, and surface water. Table 5.1 also includes a general statement regarding the applicability of the general response action to potential exposure pathways. Not all of the alternative response actions and typical technologies listed may be appropriate for OU4. Some will be discarded during the screening of alternatives.

The response actions outlined in Table 5.1 must be applied to the potential exposure pathways that will be identified for OU4. The response actions can be capable of providing control over all or some of the potential pathways. Partially effective response actions can be combined to form complementary sets of response actions that provide control over all pathways.

In general terms, potential human exposure can be avoided by prevention of contaminant release, transport, and/or contact. Thus, application of the response actions may be considered at three different points in each potential exposure pathway (1) at the point where the contaminant could be released from the source, (2) in the transport medium, and (3) at the point where the contact could occur with the released contaminant.

The existing data do not adequately characterize the source, release mechanisms, and migration pathways for contamination at OU4. Therefore, the existing data are not sufficient for implementing the screening of alternatives. Phase I will generate data (Table 5.2) necessary to characterize the source and soils (as defined in Section 1.0). Phase II of the RFI/RI will evaluate the impact of OU4 on surface water, ground water, air, the environment, and biota in addition to characterizing potential contaminant migration pathways. Data obtained from these investigations will:

- Describe the physical characteristics of the site
- Define sources of contamination
- Determine the nature and extent of contamination in soil, ground water, surface water, and air
- Describe contaminant fate and transport
- Describe receptors.

These data will provide information for the preliminary screening of alternatives and a thorough, comparative evaluation of the technologies with respect to implementability, effectiveness, and cost. This information will allow for informed decisions to be made with respect to the selection of preferred technologies. The FSP (Section 7.0) describes the methodology that will be followed to obtain the required information for the Phase I RFI/RI characterization.

5.7.2 Detailed Analysis of Remedial Alternatives

Sufficient data may not be generated during the Phase I investigation to allow for a detailed analysis of alternatives. The detailed analysis of each alternative will be performed when sufficient data are generated during Phase II. The detailed analysis and selection of alternatives is the process of analyzing and comparing relevant information in order to select a preferred remedial action. In accordance with the NCP, containment technologies will generally be appropriate remedies for wastes that pose a relatively low-level threat or where treatment is impracticable. Each appropriate alternative will be assessed in terms of nine evaluation criteria, and the assessments will be compared to identify the key attributes among the alternatives. Assessment in terms of eight evaluation criteria is necessary for the CMS and the subsequent Corrective Action Decision (CAD)/Record of Decision (ROD). The nine specific evaluation criteria are as follows:

1. Overall protection of human health and the environment
2. ARARs
3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, or volume
5. Short-term effectiveness
6. Implementability
7. Cost
8. State acceptance
9. Community acceptance.

These criteria are described in recently revised guidelines provided in the NCP. The first two criteria are considered threshold criteria because they must be evaluated before further consideration of the remaining criteria. The next five criteria are considered the balancing criteria on which the analysis is based. The final two criteria are addressed during the final decision-making process after completion of the CMS/FS.

5.8 TASK 8 - TREATABILITY STUDIES/PILOT TESTING

The primary purposes of a treatability study are to provide sufficient technology performance information and to reduce cost and performance uncertainties to acceptable levels so that treatment alternatives can be fully developed and evaluated during detailed analysis. The task includes efforts to evaluate whether treatability studies are necessary and, if so, to prepare for and conduct treatability studies. If remedial alternatives are developed, the data collected as part of the field investigation will be reviewed in terms of whether the alternatives can be evaluated. If additional data are required, treatability studies or field investigations will occur.

If it is determined that a treatability study is necessary, a treatability work plan will also be prepared. The plan will identify treatability tests that need to be conducted as well as the test materials and equipment needed.

The treatability work plan will discuss the following:

- Results of treatability studies at other OUs
- The scale of the treatability study
- Key parameters to be varied and evaluated, and criteria to be used to evaluate the tests
- Specifications for test samples, and the means for obtaining these samples
- Test equipment and materials, and procedures to be used in the treatability test
- Identification of where and by whom the tests and any analytical services will be conducted, as well as any special procedures and permits required to transport samples and residues and conduct the test
- Methods required for residue management and disposal
- Any special QA/QC needed for the tests.

5.9 TASK 9 - PHASE I RFI/RI REPORT

The Phase I RFI/RI report will be prepared to consolidate and summarize the data obtained during the Phase I fieldwork as well as data collected from previous and ongoing investigations. The Phase I RFI/RI report will consist of a Preliminary Site Characterization Summary and a BRA of the Solar Ponds area and adjacent vadose-zone soils. This report will:

- Describe the field activities that serve as a basis for the Phase I RFI/RI report. This will include the scope of the Phase I investigation and any deviations from the Work Plan that occurred during implementation of the field investigation.

- Discuss site physical conditions based on existing data and data derived during the Phase I RFI/RI. This discussion will include surface features, climate, surface water hydrology, surficial geology (vadose-zone soils), geotechnical soil index properties and classification, stratigraphy, ground water hydrology, demography and land use, and ecology.

- Present site characterization results from all Phase I RFI/RI activities to characterize the site physical features and contamination at OU4. The media to be addressed will be limited to contaminant source and soils.

- Discuss contaminant fate and transport based on existing information. This discussion will include a preliminary identification of potential contaminant migration routes, release sources and mechanisms, and a discussion of contaminant persistence, chemical attenuation processes, and potential receptors.

- Present a Phase I BRA. The BRA will include human health and environmental evaluations.

- Present a summary of findings and conclusions.

- Identify data needs for Phase II of the RFI/RI, if necessary.

Before submittal of the Phase I RFI/RI report, a Preliminary Site Characterization Summary will be submitted to EPA and CDH for review. This summary will provide an early description of the initial site characterization effort, including a preliminary presentation of analytical data and a listing of chemical and radiological contaminants, the affected media, and potential sitewide chemical-specific ARARs. In addition to the characterization summary, technical memoranda will be prepared with the completion of each field sampling task to provide preliminary results of field investigations.

TABLE 5.1

GENERAL RESPONSE ACTIONS, TYPICAL ASSOCIATED REMEDIAL TECHNOLOGIES, AND EVALUATION

General Response Action	Description	Typical General Response Technologies	Action to Potential Pathways
No Action	No remedial action taken at site	Some monitoring and analyses may be performed.	National Contingency Plan requires consideration of no action as an alternative. Would not address potential pathways, although existing access restriction would continue to control on-site contact.
Access and use restrictions	Permanent prevention of entry into contaminated area of site. Control of land use.	Site security; fencing, deed use restrictions; warning signs.	Could control on-site exposure and reduce potential for off-site exposure. Some site security fencing and signs are in place. Additional short-term or long-term access restrictions would likely be part of most remedial actions.
Containment	In-place actions taken to prevent migration of contaminants.	Capping; ground water containment barriers; soil stabilization; enhanced vegetation.	If applied to source, could be used to control all pathways. If applied to transport media, could be used to mitigate past releases (except air).
Pumping	Transfer of accumulated subsurface or surface contaminated water, usually to treatment and disposal.	Ground water pumping.	Applicable removal of contaminated ground water.
Removal	Excavation and transport of primarily nonaqueous contaminated material from area of concern to treatment or disposal area.	Excavation and transfer of soils, contaminated structures.	If applied to source, could be used to control all pathways. If applied to transport media, will control corresponding pathway. Must be used with treatment or disposal response actions to be effective.

TABLE 5.1

GENERAL RESPONSE ACTIONS, TYPICAL ASSOCIATED REMEDIAL TECHNOLOGIES, AND EVALUATION
(continued)

General Response Action	Description	Typical General Response Technologies	Action to Potential Pathways
Treatment	Application of technology to change the physical or chemical characteristics of the contaminated material. Applied to material that has been removed.	Solidification; biological, chemical, and physical treatment.	Applied to removed source material; could be used to control all pathways. Applied to removed transport media, could control air, surface water, ground water, and sediment pathways.
In-Situ Treatment	Application of technologies in-situ to change the in-place physical or chemical characteristics of contaminated material.	In-situ vitrification; bio-remediation.	Applied to source, could be used to control all pathways. Applied to transport media, could be used to control corresponding pathways.
Storage	Temporary stockpiling of removed material in a storage area or facility prior to treatment or disposal.	Temporary storage structures.	May be useful as a means to implement removal actions, but definitely would not be considered a final action for pathways.
Disposal	Final placement of removed contaminated material or treatment residue in a permanent storage facility.	Permitted landfill; repositories.	With source removal, could be used to control all pathways. With removal of contaminated transport media, could be used to control corresponding pathway (except air).
Monitoring	Short-and/or long-term monitoring is implemented to assess site conditions and contamination levels.	Sediment, soil, surface water, and ground water sampling and analysis.	RCRA requires post-closure monitoring to assess performance of closure and corrective action implementation.

TABLE 5.2

RESPONSE ACTIONS, REMEDIAL TECHNOLOGIES, AND DATA REQUIREMENTS

General Response Actions	Associated Remedial Technologies	Data Purpose	Data Need
Complete or partial removal and treatment of contaminated soils	• Disposal (off-site)	Evaluate RCRA land ban and radioactivity restrictions	- 40 CFR 268 Table CCWE and Appendix III Analyses - Full suite of radionuclide analyses
		Cost analysis	- Vertical and horizontal extent of contamination
In-situ contaminated soils treatment	• Immobilization	Determine viscosity of grout material	- Soil grain size distribution (sieve analysis)
		Effectiveness	- Full suite of organic and inorganic analyses
	• Soil flushing	Effectiveness	- Full suite of organic and inorganic analyses - Soil organic matter content - Soil classification - Soil permeability - Treatability study
	• Vapor extraction	Effectiveness	- Full suite of organic and inorganic analyses - Subsurface geological characteristics - Depth to ground water - Soil permeability - Treatability
	• Vitrification	Cost effectiveness	- Full suite of organic and inorganic analyses - Treatability study
Ground water collection	• Well array/subsurface drains	Storativity (transient flow)	- Aquifer tests

TABLE 5.2

RESPONSE ACTIONS, REMEDIAL TECHNOLOGIES, AND DATA REQUIREMENTS
(continued)

General Response Actions	Associated Remedial Technologies	Data Purpose	Data Need
Infiltration and ground water containment controls	• Capping/subsurface barriers	Suitability of off-site soil for use	- Gradation (sieve analysis) - Atterberg limits (plasticity tests) - Percent moisture - Compaction (proctor) - Permeability (triaxial permeability) - Strength (triaxial or direct shear)
		Effectiveness	- Location of subcropping sandstones - Hydraulic conductivity of bedrock materials
		Construction feasibility	- Grade - Depth to bedrock
In-situ ground water treatment/immobilization	• Immobilization	Determine viscosity of grout material	- Soil grain size distribution (sieve analysis)
		Effectiveness	- Full suite of organic and inorganic analyses
	• Aeration	Effectiveness	- Full suite of organic and inorganic analyses - Subsurface geological characteristics - Depth to ground water - Soil permeability - Treatability study

TABLE 5.2

RESPONSE ACTIONS, REMEDIAL TECHNOLOGIES, AND DATA REQUIREMENTS
(continued)

General Response Actions	Associated Remedial Technologies	Data Purpose	Data Need
Ground water/surface water treatment	• UV/peroxide or UV/ozone	Process control	- Iron and manganese
		Effectiveness	- Full suite of organic and inorganic analyses - Treatability study
	• Air stripping	Process control	- Hardness
		Effectiveness	- Full suite of organic and inorganic analyses - Treatability study
	• Other water treatment technologies (carbon adsorption, ion exchange, electrodialysis, and reverse osmosis)	Process control	- Full suite of organic and inorganic analyses
		Effectiveness	

Approved By:

8/12/92
Work Plan Manager (Date)

8/13/92
Division Manager (Date)

Effective Date: August 31, 1992

7.0 FIELD SAMPLING PLAN

The purpose of this section of the Work Plan is to provide a Field Sampling Plan (FSP) which outlines the activities which will generate sufficient and adequate data to satisfy the Phase I RFI/RI objectives developed in Section 4.0. These OU-specific objectives are presented in Section 7.1. Current site conditions and a discussion of the rationale for the sampling and analysis activities needed to obtain the necessary data to meet the Phase I objectives are summarized in Section 7.2.

The sampling activities proposed to meet the Phase I RFI/RI objectives for each location are presented in Section 7.3. Sampling activities include:

- OU-wide radiological survey and surficial soil sampling;
- OU-wide vadose zone monitoring;
- Field sampling and geophysical investigation in the vicinity of the Original Pond;
- Field sampling and geophysical investigation of the existing Solar Ponds area;
- Field sampling and investigation of the Interceptor Trench System and site remainder.

The analytical program, including sample designations, analytical requirements, sample containers and preservations, sample labeling and documentation is discussed in Section 7.4. Data management and reporting requirements are described in Section 7.5, and Field QC Procedures in Section 7.6.

Air Monitoring Surveillance activities are described in Section 7.7. Health and Safety concerns for the Phase I RFI/RI will be addressed in a project-specific Health and Safety Plan, developed at a later date in accordance with EG&G's site-wide Health and Safety Program.

Phase II of the RFI/RI will use the characterization of source and soils information obtained in Phase I and will determine the nature and extent of contamination, describe contaminant fate and transport, and evaluate the impact of OU4 on surface water, ground water, air, and biota. Phase II activities will be addressed in a separate Work Plan.

7.1 OU4 PHASE I RFI/RI OBJECTIVES

The specific objectives for characterizing source and soils in the Phase I RFI/RI field investigation for OU4 are as follows:

Characterize Original and Existing Solar Ponds

1. Characterize location, type of contaminants, variation in contaminants and other unique characteristics of the Original Pond.

2. Evaluate relative significance of pond liner material as potential sources of contamination, and effectiveness of liners as barriers to contaminant migration.

3. Characterize surficial soil in vicinity of ponds potentially contaminated by aerosol dispersion.

4. Characterize location and type of contaminants, variation in contaminants, hydrologic features, and other unique characteristics of vadose zone contamination in the Solar Ponds area.

5. Locate and identify subsurface features such as piping, tanks or structures in the vicinity of the Solar Ponds.

6. Identify subsurface geologic structures that provide a potential pathway for contaminant migration in the Solar Ponds vicinity, including subcropping sandstones and fractured bedrock.

Characterize Interceptor Trench System

1. Evaluate the construction of the Interceptor Trench System (ITS) in an attempt to assess its effectiveness in intercepting Solar Pond contaminants in ground water.

2. Characterize location, type of contaminants, and variability in contaminant concentration in unconsolidated materials in the vicinity of the ITS.

Provide a Baseline Risk Assessment

The objectives of the Baseline Risk Assessment are discussed in Sections 8.0 and 9.0.

Determine Nature and Extent of Contamination

This will be addressed in the Phase II RFI/RI Work Plan

Determine Contaminant Fate and Transport

This will be addressed in the Phase II RFI/RI Work Plan

Another objective of the Phase I RFI/RI Work Plan is to generate data necessary to begin development and screening of remedial alternatives, and to evaluate the need for the performance of treatability studies. Similarly the data will be used to determine risks to human health and the environment associated with Solar Pond contaminants.

7.2 BACKGROUND AND FIELD SAMPLING PLAN RATIONALE

Previous investigations performed in the Solar Ponds area and other pertinent information are summarized in Section 2.0 of this Work Plan. Numerous investigations have been performed previously at the Solar Ponds to characterize pond liquids, sludge, and contaminants in soil, ground water, surface water, and air quality in the vicinity. Available information at the site includes historical information on Solar Pond construction and use, aerial photographs, historical and current liquids and sludge analytical results, soil sample results from borings constructed in the area of the ponds, stratigraphic logs, ground water level measurements, ground water analytical results from alluvial and bedrock wells in the vicinity of the ponds, surface water sample analytical results from seeps and air monitoring results. As-built drawings of the ITS and analytical results from liquid samples collected from manholes in the ITS are also available.

Few previous investigations have provided information on physical characteristics of the site such as subsurface piping, geologic structures, or specifics regarding ITS configuration and effectiveness. Geophysical investigations, advanced borehole drilling and piezometer installation are proposed in this Phase I RFI/RI to provide information on physical characteristics of the OU.

Only a small portion of the soil boring analytical results for the Solar Ponds area are known to be reliable or have been validated. Most of the data is currently undergoing a validation process, and some soil boring analysis results have already been rejected for laboratory QA reasons. All available data were used to evaluate contaminant location and characteristics in this Work Plan, although most recent data were relied upon more heavily since a higher level of documented quality is associated with the more recent results.

The sampling plan discussed in Section 7.3 differs somewhat from the plan devised in the Draft Phase I RFI/RI Solar Ponds investigation. The rationale for major components of this revised Field Sampling Plan are presented in the following paragraphs.

Field Sampling Plan Rationale

The liquid and sludge in the ponds will be sampled during the IM/IRA program and Pondcreting operations, and will not be sampled in the Phase I effort. These contaminant sources have been characterized to the extent possible through historical and recent sampling, and they will be removed from the site. Prior to initiating field work in the ponds, the pond liners will be decontaminated with steam cleaners after the liquids and sludge are removed. Decontamination water will be disposed of in accordance with SOP FO.07, Handling of Decontamination Water and Wash Water. Field screening of both the pond liners and the substrate below the liners will be accomplished through the radiological survey (SOP FO.16 field radiological measurements) and volatile organic compound screening (SOP FO.15 Photoionization Detectors (PIDs) and Flame Ionization Detectors

(FIDs)). At this time, it is considered that analysis of the asphalt pond liner materials would be appropriate if the liners are to be characterized for waste disposal. However, the usefulness and accuracy of chemical analysis of the asphalt liner material for purposes of characterizing contaminant sources in the Phase I RFI/RI is very limited.

Preliminary review of the 1989 soil sampling data indicate surficial soil contamination may exist in the vicinity of the Solar Ponds. Radionuclides present in soil samples collected near the Solar Ponds are perhaps indicative of aerosol dispersion from the ponds, an observation which prompted the development of a OU-wide surficial radiological survey for alpha and gamma/beta radiation. In addition, previous analytical data did not provide an accurate representation of surficial contamination from radionuclides, metals or other pond contaminants, because near surface samples included soils collected at depths of 2 to 5.8 feet from the surface. Therefore, surficial sampling will be separated into two sampling sets. A set of ten surface soil samples will be collected in areas found to exhibit high count levels (above 250 cpm) during the radiological survey. This set will allow characterization of hot spots in the Solar Ponds area. A second set of twenty-five surface soil samples will be collected in randomly chosen locations throughout the remainder of the site. This randomly chosen set will allow correlation of the magnitude of radiological screening measurements with laboratory analyses of specific radionuclide occurrence and concentration throughout the OU.

Ground penetrating radar is proposed in the Solar Ponds area to define subsurface features such as piping, tanks, changes in lithology that could possibly delineate the location of the Original Pond, and to provide nonintrusive information on geologic strata and structures underlying the site. The rationale for selecting these methods is presented in appropriate subsections of this FSP.

Vadose zone monitoring techniques using neutron borehole logging, lysimeters and tensiometers will be further investigated for use throughout the Solar Ponds area. Preliminary research on these methods indicates the potential for investigating vadose water storage and transmission, as well as water quality. Vadose zone investigations will utilize standard operating procedures that will be developed as part of this and other plant-wide monitoring programs.

Radiological compounds in unconsolidated materials are also an indication of Solar Pond contamination. Radionuclides were detected in subsurface soil samples and ground water samples, and are thought to be attributed to Solar Pond contamination. Radiological screening will be conducted on soil cores from unconsolidated material boreholes to provide an indication of subsurface radiation, and to screen samples to be submitted for laboratory radiochemistry analysis.

Unconsolidated materials sampling will be conducted under the pond liners, in areas surrounding the ponds, and in the vicinity of the ITS. A total of 49 boreholes will be drilled in the solar ponds area; 4 within the Original Pond Area; 26 within the existing ponds area, and 18 within the ITS area and the remainder of the site. Data considered pertinent to characterization of source and soils are historical waste stream information and previous analytical results from the pond liquids and sludge, as well as new data collected to evaluate the release of contaminants to the underlying, undisturbed soil. Sampling of the pond liners themselves is not proposed in this investigation, as the liners are not considered primary sources of Solar Pond contaminants. Removing the liquids and sludge will eliminate the primary sources of contaminants. The relative significance of the liners as remaining sources of residual contamination after the liquids and sludge are removed will be evaluated in the field using radiological (SOP FO.16 Field Radiological Measurements) and volatile organic compound screening (SOP FO.15 Photoionization Detectors (PID) and Flame Ionization Detectors (FIDs)) equipment. Sampling of pond liner materials may be proposed pending results of field screening activities.

The installation of piezometers in the ITS area is proposed in this Work Plan to assist in characterizing the effectiveness of the drain in intercepting contaminated ground water. Piezometer installation will allow the hydrologic system near the main interceptor trench to be further understood, by providing water level information at several locations.

The rationale for the Phase I sampling activities is based on an iterative process. Level I and Level II data types will initially be acquired and used to direct subsequent intrusive sampling techniques that will provide Level III through V analytical results. A visual survey of pond liner condition will guide the placement of vadose zone boreholes within the ponds. Similarly, vadose zone monitoring results may be used to guide further soil and ground water investigations.

As part of the field sampling program, data from the sitewide monitoring program will be used as appropriate to supplement the data collected during the Phase I investigation. These data include the results of quarterly sampling of existing monitoring wells and monthly sampling of surface water monitoring stations. Data resulting from the site-wide geologic characterization program will also be used, where possible. Air monitoring activities conducted site-wide or in specific response to the Pond Liquids and Sludge Removal activities will also be included.

Analytical Methods Rationale

The analytical suites for each area in OU4 were developed according to the type of waste suspected to be present in each area. The rationale for the analytical suites is based on historical information regarding types of contaminants detected or reportedly disposed in the Solar Ponds. Because the field sampling program may be implemented in some locations before others, the analytical suites proposed in this Work Plan may be revised based on results of initial field efforts. Any changes to the analytical suite will need to be proposed, reviewed, and accepted by CDH and EPA before any change will be implemented.

7.3 FIELD SAMPLING PLAN DESIGN

The Phase I sampling activities at the Solar Ponds are discussed as six related, but independent programs. They include:

1. OU-wide radiological survey and surficial sampling program (Section 7.3.1)

2. OU-wide vadose zone monitoring (Section 7.3.2)

3. Determination of location and contaminant distribution in the Original Pond (Section 7.3.3)

4. Determination of vadose zone contamination and subsurface features associated with existing Solar Ponds (Section 7.3.4)

5. Investigation of unconsolidated materials and water table configuration in vicinity of the ITS and in remainder of the site (Section 7.3.5).

A review of aerial photographs and other recently collected data will be conducted prior to commencing any field work mentioned above.

7.3.1 Site-Wide Radiological Survey and Surficial Sampling Program

Historically, Pond 207-A was used for disposal of liquids containing relatively high levels of the radionuclides plutonium and americium. A preliminary radiation survey conducted on the Pond 207-A perimeters in August 1990 indicated elevated alpha readings confirming historical data regarding high radionuclide content in Pond 207-A liquids and sludge. Based on this information, a surface radiological survey is proposed to characterize low level radionuclide distribution throughout the area.

A site-wide radiological survey using alpha and gamma/beta radiation meters will be conducted on a grid system established throughout the Solar Pond area. The alpha radiological survey will be conducted in accordance with SOP F0.16. The gamma radiological survey shall follow a SOP currently under development. A 100-foot square grid will be established in the Solar Ponds area, extending from Building 771 on the west to the easternmost interceptor trench on the east, and from 1,500 feet south of the ponds to north of the ITS. The Perimeter Security Zone (PSZ) bisects this area, however, the grid will not be established inside the PSZ. Radiation measurements will be taken at all nodes of the established grid. In the Solar Pond area south of the PSZ, measurements will be increased to include a supplemental point at the center of each 100-foot grid square. Measurements are proposed at approximately 350 locations in the surface radiological survey, depicted on Figure 7-1. The radiological survey will be conducted in coordination with activities at adjacent operable units to minimize duplication of effort.

Prior to conducting the survey, the survey points will be paced and/or taped off. If a structure or other obstruction makes conducting measurements at the node difficult, the survey location will be moved to the closest location where readings may be taken. Additional survey points may be established in the field in areas suspected of having elevated radionuclides, including surface water seep locations and pond liner cracks. After measurement, locations will be surveyed using standard land surveying techniques. Field team members will coordinate with ongoing operations personnel to ensure that stakes or flagging used to identify sampling locations are not moved or damaged by ongoing waste operations prior to surveying.

The survey will be conducted in accordance with SOP FO.16, Field Radiological Measurements, and additional surface radiation survey SOPs currently under development by EG&G that will govern the use of high-purity germanium gamma-ray detection equipment.

The survey may be conducted in phases as access to areas such as the cleaned ponds becomes feasible. Each grid node will be identified with a unique station number using alphabetical and numeric grid identifiers such as A-1 or B-3 where letters are assigned to rows and numbers assigned to columns. Any survey readings taken at nonstandard grid locations will also be given a unique identifier.

Alpha radiation is measured much closer to the soil than gamma radiation. The alpha counter will be held parallel to and within ¼-inch of the surface being screened and a minimum of two readings will be taken at each grid node. Alpha readings will be collected at eight locations equidistant around a five foot radius circle at the surveyed location. The eight readings will be recorded and the highest and lowest value identified. Gamma and alpha readings will be recorded on data sheets which can be related to field location maps. The data sheet to be used is Form F0.16A, which is contained in SOP F0.16. Additional readings may be collected at anomalously elevated areas, although no more than 50 additional survey locations will be added.

Surficial Sampling

Approximately 35 surficial soil samples will be collected and analyzed. Surficial soil samples will be separated into 2 sampling sets. A set of 10 surface soil samples will be collected in areas found to exhibit high count levels during the radiological survey. Monitoring results greater than 250 cpm as indicated by the Ludlum 12-1A will be considered indicative of the presence of radiological contamination at the surface and will be considered for surficial soil sampling. Field specified sample collection based on radiological measurements will help identify hot spots in the Solar Ponds area. A second set of 25 surface soil samples will be collected in randomly chosen locations throughout the remainder of the site. Randomized sample collection will allow subsequent correlation of radiation survey measurements with laboratory analyses of specific radionuclide occurrence and connection. Methods for selecting random sample locations will be evaluated as part of the Phase I RFI/RI Project Planning Task.

In accordance with procedures in SOP GT.8, two one-meter square areas located one meter apart will be established at each surficial sampling location. If asphalt or other barriers prevent the collection of a surficial sample, the location will be moved to the closest accessible location. From the two square meters, a minimum of five soil samples will be collected from each of the corners and the center of each square meter. Additional samples may be collected in order to obtain a sufficient sample volume for analysis. Samples will be collected from the surface to a depth of ¼-inch in an area 2 inches wide and 2-3/4 inches long using a CDH sampler. The samples will be composited in a large stainless steel bowl or pan and stirred with a stainless steel scoop or spoon. Duplicate samplers will also be collected using the grab method, also outlined in SOP GT.8, at 10 to 20 percent of the sample locations to evaluate comparibility between methods. Sample handling will be conducted in accordance with SOP FO.13, Containerizing, Preserving, Handling, and Shipping Soil and Water Samples. Sampling equipment will be decontaminated between individual sampling points in accordance with SOP FO.3, General Equipment Decontamination. Documentation of the surficial soil sampling activity at the Solar Ponds will be in accordance with SOP GT.8.

7.3.2 Site-Wide Vadose Zone Monitoring

Vadose zone monitoring techniques can be used to investigate water storage and transmission characteristics, as well as fluid quality. Such monitoring represents an innovative and cost effective means of delineating active contaminant migration pathways. In addition, the response of these active pathways to remediation and closure activities can also be monitored and documented through time. Although specific monitoring locations and methods have not been identified, preliminary vadose zone monitoring objectives and potentially applicable techniques are discussed in this section. A detailed work plan will be developed as a work element within the OU4 Phase I RI/RFI effort, and will be presented as a technical memorandum. Standard operating procedures will be developed in coordination with other OUs to ensure consistency.

Preliminary objectives for vadose zone investigations include characterization of active vadose zone migration pathways and development of methodologies for closure and post-closure monitoring. In order to accomplish these objectives, the following activities are envisioned:

- Characterization of infiltration, vadose zone storage, and water table recharge in the Solar Evaporation Ponds area;
- Determination of vadose zone storage and downwind transmission of infiltration in response to precipitation events;
- Correlation of potential perched water horizons between the Solar Evaporation Ponds area and downslope seeps; and
- Evaluation of sample collection techniques and investigation of vadose water quality.

Methods for conducting these investigations are discussed by Nielsen (1991) and Everett et al. (1984). The suitability of these methods will be evaluated in greater detail during preparation of the OU4 vadose zone investigation work plan. Initially, a pilot program is envisioned to allow adequate testing of these techniques. Several possible approaches are presented below.

Surface infiltration rates can be measured using a double ring infiltrometer, and the resulting data used to calculate a saturated hydraulic conductivity. Application of saturated hydraulic conductivity to the vadose zone will provide a conservative estimate of fluid transmission rates. Measurement of vertical variations in moisture content in response to precipitation events using neutron borehole logging techniques can yield empirical estimates of fluid transmission rates. By comparing repeated measurements of moisture content as a function of depth, a wetting front indicative of downward fluid transmission may be observed. This rate of downward movement can then be compared to calculated rates based on double ring infiltrometer measurements. Knowledge of the rate and volume of contaminants. Of particular interest are the effects of changing source conditions associated with pond dewatering and eventual closure. Neutron logging of selected boreholes over time may yield invaluable information regarding the long-term impacts of vadose zone contaminants on ground water quality.

Neutron logging can be used to identify saturated horizons indicative of perched water conditions. These perched water horizons can then be correlated between boreholes in an attempt to identify lateral migration pathways. Perched water pathways may be important in understanding the hydraulics of pond seepage and the hydrogeologic relationship between the solar evaporation ponds and surface seeps located downslope.

Identification of subsurface zones of high moisture content may also allow optimization of vadose water sampling locations and depths. Tensiometers can be installed in these high moisture zones to measure soil matric potential. These measurements can be used, in turn, to evaluate the feasibility of collecting vadose water, and determine optimal conditions for sample collection. After selection of appropriate sampling locations and depths, suction lysimeters can be installed to allow collection of vadose water samples. The volume of sample collected will dictate analytical suite, methods, and associated detection limits, as well as data quality level generated. Comparison of even basic water quality parameters with infiltration, storage, and transmission rates may yield significant information regarding temporal changes in vadose zone contaminant flux to ground water.

7.3.3 Original Pond Area

Proposed field activities and a geophysical investigation at the Original Pond area are shown on Figure 7-2. In order to define the boundaries of the Original Pond, activities proposed in this section will be preceded by an aerial photograph review, engineering drawings review, and evaluation of other historical documentation. A surface radiological survey and surficial soil sampling program will be conducted as described in Section 7.3.1. Subsequent field activities include a geophysical survey and drilling of four boreholes through the unconsolidated materials with collection of subsurface samples for chemical analysis. Each of these activities is described below.

7.3.3.1 Geophysical Investigation

A surface geophysical investigation employing ground penetrating radar (GPR) will be performed in the area on and around the Original Pond. The survey will be conducted in accordance with guidelines provided in SOP GT.18. The primary objectives of this survey are to locate the boundaries of the Original Pond, and to locate any piping or other fittings not removed at the time the pond itself was removed. An inventory of RFP piping and its configuration is currently being compiled in the Original Process Waste Lines (OPWL) investigation. Preliminary information reviewed from the OPWL investigation shows underground piping and possibly tanks in the immediate vicinity of the Original Pond. It must be noted that the abundance of cultural features throughout OU4 may limit the results of the proposed geophysical investigation. In the event that the GPR survey is unsuccessful, physical characteristics of the Original Pond Area will be evaluated using background information and the information obtained from the borings completed.

Theory of Operation

Ground Penetrating Radar (GPR) utilizes an electromagnetic pulse source, source and receiver antennas, and a graphic recorder to map reflections from subsurface interfaces caused by buried objects and distinct stratigraphic horizons. For a reflection to occur, an impedance contrast, which is related to the dielectric constant and conductivity of the respective materials, must be present across any such interface(s).

The GPR instrument consists of a microprocessor-based control unit, a graphic recorder, and a combined source/receiver antenna. These components are interconnected through a series of cables which:

- Carry power to the antenna
- Relay reflected electromagnetic pulses from the antenna to the control unit
- Transfer processed electromagnetic pulses from the control unit to the graphic recorder.

A number of antennas are available at frequencies which range from 80 Megahertz (Mhz) to 900 Mhz. Typically, a lower frequency antenna, such as 80 Mhz, will permit greater signal penetration but with less resolution, whereas a higher frequency antenna, such as a 900 Mhz, offers greater resolution but with less signal penetration. The depth of underground piping or any remaining clay liner material from the Original Pond will guide selection of antenna frequency.

GPR data is collected by slowly pulling the antenna across the ground surface. A paper record output by the graphic recorder during each of the "traverses" is annotated in the field with the traverse location, horizontal scale, full-scale time display, and the antenna used.

Field Methodology

The GPR survey design, field procedures and documentation of activities will follow those outlined in SOP GT.18. Prior to beginning GPR data collection, a grid will be surveyed on and around the reported location of the Original Pond. Use of the grid will permit the systematic collection of data from the area. After a survey is completed in the reported pond location, the grid will be expanded to the areas surrounding the existing Solar Ponds for subsequent data collection. Key points on the grid will be surveyed in and referenced to the site coordinate system. The approximate area included in the grid system is shaded in Figure 7-2.

Data will be collected by locating the GPR traverses on appropriate grid lines and the antenna pulled slowly along the surface. At least two antennas will be tested, with the one offering the best combination of target resolution and signal penetration being utilized for the survey. All GPR records will be annotated with the traverse location, horizontal scale, full-scale time display, antenna used, and the location of any anomalies observed. Also, the surface on which each traverse is located will be inspected for the presence of features which could cause an anomaly. Initial GPR records will be inspected closely to determine if the task objectives being accomplished. A recommendation will be made to EG&G personnel as to whether or not to proceed with GPR data collection.

Following GPR data collection, all anomalies observed will be indicated in two ways:

- Stakes will be placed in the ground along the periphery of the Original Pond as interpreted from the GPR records. Stakes will be placed in the ground above any lines, tanks or other objects, the location of which are interpreted from the GPR records.

- The locations of all objects indicated by stakes in the ground will be surveyed and accurately marked on a map of suitable scale.

The resultant map will be checked against known locations and uses of underground piping inventoried in the OPWL investigation. The relative importance of the presence of these subsurface features will be assessed. Any relative differences observed in areas within and outside of the Original Pond area will be used to guide unconsolidated material borehole placement and sampling.

After completion of the survey, all records collected will be compiled and filed for future reference.

7.3.3.2 Unconsolidated Materials Investigation

The unconsolidated material conditions in the vicinity of the Original Pond will be investigated by drilling boreholes, collecting soil samples and performing chemical analysis. The purpose of the borings is provide information on soil chemistry in near-surface and subsurface soils, identify old clay liner material (if present), provide information on depth to ground water, and provide information on weathered bedrock underlying the Original Pond, if encountered. Boreholes will be drilled at four locations in the Original Pond area. Preliminary borehole locations are shown in Figure 7-2, although the locations may be adjusted using results from the surface geophysical survey, radiological survey, and borehole clearing in accordance with SOP GT.10. Three borings will be placed within the reported Original Pond area, and one will be placed outside the pond location to provide a reference for evaluating whether effects from the Original Pond can be delineated.

To compliment the surficial soil sampling program described in Section 7.3.1, a surficial soil sample will be collected at each borehole location and analyzed for TCL-Volatiles (Table 7.1). Concrete or asphalt encountered at borehole locations will be removed. Procedures for sample collection are as described in Section 7.3.1.

Drilling will be performed using hollow-stem augers and unconsolidated materials will be continuously sampled. The unconsolidated material borehole locations will be cleared according to SOP GT.10, and installed using a truck-mounted and/or skid or trailer-mounted hollow-stem auger drilling rig, as may be required for access. A 2-foot-long continuous sampler will be used, and soil and bedrock cores will be geologically classified using both engineering Unified Soil Classification System (USCS) classifications and Soil Conservation Service (SCS) soil series identifiers. Drilling and sampling will follow procedures established in SOP GT.2. Airborne contaminant dispersion will be minimized in accordance with SOP F0.1. Logging the alluvial and bedrock material will be in accordance with guidelines specified in SOP GT.1 with the addition of SCS soil series horizon identification.

Boreholes will be advanced until either saturated soils are encountered or auger refusal. Total bedrock penetration in these borings will not exceed approximately five feet. This will be the general criteria for limiting the depth of boreholes except where delineation of the Arapahoe sandstones is an objective (see Section 7.3.6.1). An average total boring depth of 15 to 20 feet is envisioned. Soil cores will be collected at 2-foot increments to enhance sample recovery as described in SOP GT.2.

Each two-foot core will be screened while samples are being logged using hand-held field instruments for alpha and beta/gamma radiation, as well as VOCs according to SOP GT.1. A laboratory-quality alpha detector and sodium-iodide, beta/gamma detector that reads in counts per minute will be used. At a minimum, a photo-ionization detector will be used to detect VOCs emitting from samples. Results of the radioactive content and VOC screening may be used to alter standard interval selection for chemical analysis.

Samples will be composited from three 2-ft cores as described in SOP GT.2 and submitted for the parameters listed in Section 7.4.2. Samples will be selected at a minimum of 5-foot intervals from near the ground surface to the water table. Additional samples will be selected at changes in lithology and from zones that have indications of contamination as determined from visual inspection of the samples or field instrument screening for organics and radionuclides.

Geophysical borehole logging using natural gamma, neutron, and restivity tools will be conducted in all boreholes advanced for geologic investigation to allow further characterization of subsurface materials and ground water. Downhole logging will be conducted in accordance with SOP GT.15.

Collected samples will be placed in appropriate containers for analytical testing according to SOP FO.13, Containerizing, Preserving, Handling, and Shipping of Soil and Water Samples. Radiation field screening and sample preparation for radiological analysis will be conducted in accordance with SOP F0.18. Vadose zone monitoring instruments may be emplaced into the subsurface prior to abandoning the boreholes.

Once all information is obtained from a subsurface boring, the borehole will be abandoned in accordance with SOP GT.5. Before proceeding to the next boring location, equipment will be decontaminated to avoid cross contamination in accordance with SOP FO.3, General Equipment Decontamination, SOP F0.4 Heavy Equipment Decontamination, and SOP F0.12 Decon Facility Operations. Environmental waste produced during drilling will be drummed and handled according to SOP F0.10.

7.3.4 Existing Solar Ponds Area

Proposed field activities and geophysical investigation at the existing Solar Ponds area are shown on Figure 7-3. Activities proposed in this section are preceded by a review of facility engineering drawings, aerial photographs, the surface radiological survey and surficial soil sampling program described in Section 7.3.1. Field activities include a visual survey to determine locations of cracks in the pond liners, a geophysical survey to identify subsurface piping in the pond vicinity, and drilling of boreholes through the pond liner and on pond perimeters to investigate the unconsolidated materials below. Soil samples will be collected for chemical analyses in all unconsolidated material boreholes. Each of these activities is described below.

7.3.4.1 Visual Inspection

Prior to conducting the geophysical investigation, or intrusive borehole construction, a visual inspection will be conducted in the existing ponds area. The proposed perimeter borehole locations will be checked against the presence of obstructions, accessibility of the drilling rig, or other constraints not previously addressed. Once the liquids and sludge are removed from the Solar Ponds, the liners of all five ponds will be observed and cracks or other evidence of deterioration marked on a location map. Photographs of each pond will be taken to document deteriorated liner areas and general pond condition during the visual survey. The most damaged liner locations will be considered for sampling. Placement of unconsolidated material borings will be influenced by the results of the pond liner survey.

7.3.4.2 Geophysical Investigation

A ground penetrating radar (GPR) survey will also be performed in the areas surrounding the existing Solar Ponds. The objective of this survey is to locate piping and any other buried objects in the area. This survey will consist of an expansion of the survey performed in the Original Pond area and will employ similar instruments and techniques. The general vicinity of the Solar Ponds geophysical survey is shaded on Figure 7-3.

Field Methodology

The GPR survey design, field procedures, and documentation of activities will follow those outlined in SOP GT.18. The survey of the existing Solar Ponds area will follow the completion of the survey in the Original Pond area. The survey grid and parameters will be adjusted according to the results of the Original Pond survey. GPR data collection will be performed in the same manner as the survey in the Original Pond area.

7.3.4.3 Unconsolidated Material Investigation

The vadose zone investigation in the existing pond area will consist of borehole installation on the pond perimeters and within the ponds themselves. Twenty six borings are proposed in and around the existing Solar Ponds as shown on Figure 7-3. Five borings are proposed within Pond 207-A, and three are proposed in each of the remaining ponds. Nine perimeter borings will be placed on the pond exteriors. Boreholes constructed inside the ponds will be placed both at locations where cracks are observed, and where the liner integrity appears to be intact. Comparison of results from boreholes placed in such a manner may provide information to estimate patterns of pond leakage, including major contaminant migration pathways. Analytical results from the perimeter borings will be used to characterize lateral migration of pond contaminants in vadose zone soil. These perimeter borings will be placed in or as near pond embankments as is accessible. Borings will be angle drilled beneath the embankments if deemed necessary.

The asphalt liners in the area of the borehole will be excavated with either an air driven or electric-powered jackhammer in an area of adequate size for sampling. The use of a jackhammer will not require introduction of water as is required with typical asphalt or concrete coring equipment. Base course material will be removed using a small shovel or other tool to reveal undisturbed alluvial material below. Health and Safety radiological and VOC measurements will be taken on removed liner and base course material using field screening instruments. Samples of the 0 to 1 inch depth interval will be collected from undisturbed material below the liners using the procedures described in the Surficial Soil Sampling Program, except that only one 1-meter square will be sampled.

A drilling investigation of unconsolidated materials will be performed as described in Section 7.3.2. A skid- or track-mounted drilling rig may be required due to limited pond access. Drilling depths are expected to vary from 15 to 20 feet for the boreholes inside and on the perimeters of the Solar Ponds. Proposed sample collection procedures and requested analytes are the same as those described for unconsolidated material borings in the Original Pond area. The proposed drilling procedure, sampling procedure and analytical suite are subject to revision or refinement based on results of unconsolidated material sampling conducted in other areas of the Solar Ponds.

7.3.5 Interceptor Trench System and Remainder of Site

Proposed field activities at the ITS and remainder of the site are shown on Figure 7-4. Activities proposed here are preceded by a review of system as-built drawings in Appendix A, and a surface radiological survey and surficial soil sampling program described in Section 7.3.2. Field activities include the installation of piezometers in several locations up and downgradient of the ITS to determine hydrological characteristics of the system, and drilling of boreholes in outlying areas of the ponds and in the ITS area to investigate the unconsolidated materials. Soil samples will be collected for chemical analyses in all unconsolidated materials boreholes.

A geophysical investigation employing seismic refraction and high resolution seismic reflection was considered for investigating the ITS and other selected portions of the site. However, a technical evaluation of these geophysical techniques found that the use of geophysics would be ineffective. The use of other investigatory methods to determine the effectiveness of the ITS will be further considered and evaluated based on the results of this Phase I investigation.

7.3.5.1 Unconsolidated Materials Investigation

The unconsolidated materials investigation in the vicinity of the ITS and in outlying areas of the site will be accomplished with borehole construction and soil sampling. Borehole drilling and sampling procedures will be performed as discussed in previous sections. Figure 7-4 shows the proposed location for the 18 boreholes in the ITS area and remainder of site. Eight of the eighteen borings are located in the ITS area. The objective of drilling the borings is to provide soil774 contaminant information at relatively far distances from the ponds, compare soil contaminants in borings located up and downgradient of the ITS.

A subset of 5 proposed borings in the Solar Pond area are to be advanced deeper than is described in standard drilling and sample collection procedures. These borings are identified in green on Figure 7-4. Specific objectives are to delineate the Arapahoe sandstone and visually determine the presence or absence of fractures in bedrock. The Arapahoe sandstone is potentially a path of contaminant migration because of its higher hydraulic conductivity relative to the Arapahoe claystone and its location below pond 207-C and the northwest corner of 207-A. Therefore, it is important to further delineate the paleochannel in the vicinity of the Solar Ponds with the proposed 5 borings. A bedrock topography map incorporating additional data collected from the Phase I soil boring will be presented in the final report. The proposed borehole location will be reevaluated prior to drilling and change as necessary to incorporate any new data or geologic interpretations.

Boreholes will be advanced to a total depth range of about 40 to 60 feet in order to delineate the extent of sandstone lenses subcropping in the bedrock. Procedures for advancing these borings past the depth required for environmental sampling will follow guidelines in SOP GT.4, Rotary Drilling and Rock Coring. Prior to drilling borings that advance into weathered bedrock, a surface casing will be installed according to SOP GT.3, Isolating Bedrock from the Alluvium with Grouted Surface Casing. Each 2-foot core will be screened for alpha and beta/gamma radioactivity, as well as volatile organic compounds with field instruments while samples are being logged.

Contaminants likely to be detected in soil samples from these borings include those that are relatively soluble and were transported through ground water flow. For this reason, collecting soil samples immediately above the water table is a primary objective of these borings. Samples will be collected as described in Section 7.3.4.2.

7.3.5.2 Piezometer Installation

Piezometers will be installed immediately upgradient and downgradient of the primary interceptor trench to provide information on the water table configuration at the trench. Existing data regarding water table configuration, alluvial hydraulic conductivity, trench geometry, and withdrawal rates within the ITS area will be used to optimize piezometers spacing. These data will be used to determine piezometer spacing using analytical or numerical simulations of aquifer drawdown to estimate the interceptor trench area of hydraulic influence. Locations may be modified based on the results of initial water table measurements. Measurement of water table configuration near the interceptor, and response to precipitation events, will allow evaluation of system effectiveness. The use of ground water tracers or additional piezometers to monitor flow immediately toward and downgradient of the interceptor will also be considered as a Phase II activity following analysis of hydraulic data.

Piezometer installation procedures will be in accordance with SOP GT.6. Because unsaturated alluvial conditions are believed to exist in the western and central portions of the ITS, the proposed piezometers have been sited in the eastern segments of the system. Installation of the piezometers at two locations parallel to the assumed ground water flow direction is proposed, and at two locations perpendicular to flow direction. Piezometers installed perpendicular to flow will provide information on the finger trenches upgradient of the interceptor trench pump house. Water level measurements will be made in accordance with GW.1.

7.4 SAMPLE ANALYSIS

This section describes the sample handling procedures and analytical program for samples collected during the Phase I investigation. This section also includes discussions of sample designation, analytical requirements, sample containers and preservation, and sample handling and documentation.

7.4.1 Sample Designation

All sample designations generated for the RFI/RI will conform to the input requirements of RFEDs, as described in SOP FO.14A. Each sample designation will contain a nine-character sample number consisting of a two-letter prefix identifying the media samples (SB for soil boring, SS for surficial soils), a unique five-digit number, and a two letter suffix identifying the contractor. One sample number will be required for each sample generated including QC samples. In this manner, 99,999 unique sample numbers are available for each sample media for each contractor that contributes sample data to the data base. Boring numbers will be developed independently of the sample number for a given boring. These sample numbering procedures are consistent with the RFP site-wide QAPjP.

7.4.2 Analytical Requirements

The analytical suites for surficial soil samples and unconsolidated material samples were developed according to the types of contaminants detected historically in the Solar Pond and adjacent areas, as well as their geochemical behavior. Specific analytes in the above groups and their CLP detection/quantitation limits are listed in Table 7.1. These analytes and limits should address the chemicals that have been previously detected in pond liquids and sludge, the sources for OU4.

Unconsolidated material samples from the Phase I RFI/RI collected in the Original and existing Solar Pond investigation will be analyzed for all of the following chemical and radionuclide parameters or parameter groups.

- Nitrate
- Target Analyte List (TAL) Metals
- Uranium 233/234, 235, 236 and 238
- Plutonium and Americium
- Cesium 137 and Strontium 90
- Gross Alpha and Gross Beta
- Tritium
- TCL volatile organics (subsurface samples only)
- TCL semivolatile organics
- Inorganics
- Pesticides.

Surficial soil samples will be analyzed for only a subset of these parameter groups including:

- Nitrate
- TAL Metals
- Uranium 233/234, 235, 236 and 238
- Plutonium and americium
- Cesium-137 and Strontium-90
- Gross alpha and gross beta
- Tritium
- TCL semivolatile organics.

A restricted suite of analyses will be conducted on unconsolidated material samples collected from within the interceptor trench system and the remainder of the site. The restricted analytical suite has been designed to characterize soil contaminants previously identified in these areas. Contaminants not previously observed above background concentrations in subsurface soils from these areas have been eliminated. In the event that sampling of the Original and existing Solar Pond Areas indicates that eliminated parameters may be of concern in unconsolidated soils of the Interceptor

Trench System and the remainder of the site, the migration of these contaminants will be investigated further during Phase II of the RI/RFI.

The restricted suite of analyses proposed for unconsolidated material in the interceptor trench system and the remainder of the site include the following parameter groups:

- Nitrate
- Uranium 233/234, 235, 236 and 238
- Gross Alpha and Gross Beta
- Tritium
- TCL Volatile Organics
- Inorganics.

Ground water samples from the upgradient monitor wells will be analyzed for the full suite of compounds listed in Table 7.1. Also provided are the compounds CLP detection/quantification limits for water samples.

7.4.3 <u>Sample Containers and Preservation</u>

Sample volume requirements, preservation techniques, holding times, and container material requirements are dictated by the media being sampled and by the analyses to be performed. The soil matrices to be analyzed will include surficial soils and unconsolidated materials samples, and the water matrices for analysis will include ground water. Analytical parameters of interest in OU4 for water and soil matrices, along with the associated container size, preservatives (chemical and/or temperature), and holding times are listed in Table 7.2 and 7.3. Additional specific guidance on the appropriate use of containers and preservatives is provided in SOP FO.13, Containerizing, Preserving, Handling, and Shipping of Soil and Waste Samples. Information on preparing samples specifically for radiological analysis is provided in SOP F0.18.

7.4.4 <u>Sample Handling and Documentation</u>

Sample control and documentation is necessary to ensure the defensibility of data and to verify the quality and quantity of work performed in the field. Accountable documents include logbooks, data collection forms, sample labels or tags, chain-of-custody forms, photographs, and analytical records and reports. Specific guidance defining the necessary sample control, identification, and chain-of-custody documentation is discussed in FO.13.

7.5 DATA MANAGEMENT AND REPORTING REQUIREMENTS

The field data collected during the various investigations discussed in Section 7.3 will be documented as outlined in the specific SOPs cited. Field data will be managed according to SOP F0.2.

Field data will be input to RFEDs using a remote data entry module supplied by EG&G. Data will be entered on a 3.5-inch computer diskette and will be delivered to EG&G on a timely basis. A hard copy report will be generated from the module for contractor use. Procedures for data quality control, verification, entry into RFEDS, archiving and security will follow SOP FO.14.

A sample tracking spreadsheet will be maintained by the contractor for use in tracking sample collection and shipment. EG&G will supply the spreadsheet format and will stipulate timely reporting of information. These data will also be delivered to EG&G on 3.5-inch computer diskettes. Computer hardware and software requirements for contractors using government-supplied equipment will be supplied by EG&G. Computer and data security measures will also follow acceptable procedures outlined by EG&G.

7.6 FIELD QC PROCEDURES

Sample quality will be controlled by following the prescribed SOPs or accepted methods for sample collection, sample shipment, equipment use, equipment decontamination, and equipment calibration as discussed previously in the FSP. These procedures provide the best methods for collection of representative samples. In addition, four types of field quality control (QC) samples will be collected: sample duplicates, field blanks, trip blanks, and equipment rinsate blanks. Laboratory QC samples include laboratory method blanks spiked and surrogate samples.

The analytical results obtained for these samples will be used by the ER project manager to assess the quality of the field sampling effort. The types of field QC samples to be collected and their application are discussed below. The frequency with which QC samples will be collected and analyzed is provided in Table 7.4.

Sample duplicates will document laboratory precision, field blanks will assess impact of site conditions or environmental samples. Trip blanks will document if contamination has occurred during storage or transport of samples. Equipment rinsate blanks will document whether cross-contamination has occurred between sample collection sites.

Duplicate samples will be collected by the sampling team for use as a relative measure of the precision of the sample collection process. These samples will be collected at the same time, using the same procedures and equipment, and in the same types of containers as required for the samples. They will also be preserved in the same manner and submitted for the same analyses as required for the samples. Duplicate samples will only be collected during ground water sampling.

Field preservation blanks of distilled water, preserved according to the preservation requirements (Section 7.4.3), will be prepared by the sampling team and will be used to provide an indication of any contamination introduced during field sample preparation. As indicated in Table 7.4, these QC samples are applicable only to samples requiring chemical preservation.

Equipment rinsate blanks will be collected from final decontamination rinsate to evaluate the success of the field sampling team's decontamination efforts on non-dedicated sampling equipment. Equipment blanks are obtained by rinsing cleaned equipment with distilled water prior to sample collection. The rinsate is collected and placed in the appropriate sample containers. Equipment rinsate blanks are applicable to all analyses for water and soil samples, as indicated in Table 7.4.

Trip blanks consisting of distilled water will be prepared by the laboratory technician and will accompany each shipment of samples for volatile organic analysis. Trip blanks will be stored with the group of samples with which they are associated. Analysis of the trip blank will indicate migration of volatile organics or any problems associated with sample shipment, handling, or storage. Information from the trip blanks will be used in conjunction with air monitoring data and other information to assess the influence of ongoing waste operations on the quality of data collected.

Procedures for monitoring field QC are provided in the sitewide QAPP. The collection of QC samples will be documented on the proper soil or water sample collection logs per SOPs GT.2, GT.8, and GW.6.

7.7 AIR MONITORING SURVEILLANCE ACTIVITIES

Air monitoring will be performed during field activities to ensure that quality data are obtained during sampling and that all sampling activities comply with the Interim Plan for Prevention of Contaminant Dispersion (IPPCD) (EG&G, 1991l). Air quality monitoring will be performed in accordance with SOPs presently being developed by EG&G.

Air quality monitoring requirements for activities such as borehole drilling where there is a significant potential for producing appreciable quantities of suspended particulates include the following:

- Site perimeter and community Radiological Ambient Air Monitoring Program (RAAMP) data for radiological parameters will be available.
- Local monitoring of Respirable Suspended Particulates (RSP) at individual activity work sites shall be conducted using a TSI "Piezobalance" Model 3500 Respirable Aerosol Mass Monitor, a real-time instrument. Local RSP measurements will be used to guide the project Manager's evaluation of the potential hazards associated with activity-related emissions. The threshold RSP concentration for curtailing intrusive activities will be 6.0 milligrams/cubic meter (mg/m^3).
- Additional worker health and safety monitoring as required by the Site-Specific Health and Safety Plan (SSH&SP).

TABLE 7.1

PHASE I SOIL, SEDIMENT, AND WATER SAMPLING PARAMETERS
AND DETECTION/QUANTITATION LIMITS

	Detection Limits*	
Target Analyte List - Metals	Water (µg/l)	Soil/Sediment (mg/kg)
Aluminum	200	40
Antimony	60	12
Arsenic	10	2
Barium	200	40
Beryllium	5	1.0
Cadmium	5	1.0
Calcium	5000	2000
Cesium	1000	200
Chromium	10	2.0
Cobalt	50	10
Copper	25	5.0
Cyanide	10	10
Iron	100	20
Lead	5	1.0
Lithium	100	20
Magnesium	5000	2000
Manganese	15	3.0
Mercury	0.2	0.2
Molybdenum	200	40
Nickel	40	8.0
Potassium	5000	2000
Selenium	5	1.0

TABLE 7.1

PHASE I SOIL, SEDIMENT, AND WATER SAMPLING PARAMETERS
AND DETECTION/QUANTITATION LIMITS
(continued)

Silver	10	2.0
Sodium	5000	2000
Strontium	200	40
Thallium	10	2.0
Tin	200	40
Vanadium	50	10.0
Zinc	20	4.0

	Quantitaion Limits*	
Target Compounds List - Volatiles	Water (µg/l)	Soil/Sediment (µg/kg)
Chloromethane	10	10
Bromomethane	10	10
Vinyl Chloride	10**	10
Chloroethane	10	10
Methylene Chloride	5	5
Acetone	10	10
Carbon Disulfide	5	5
1,1-Dichloroethene	5	5
1,1-Dichloroethane	5	5
trans 1,2-Dichloroethene	5	5
Chloroform	5	5
1,2-Dichloroethane	5	5
2-Butanone	10	10
1,1,1-Trichloroethane	5	5

TABLE 7.1

PHASE I SOIL, SEDIMENT, AND WATER SAMPLING PARAMETERS AND DETECTION/QUANTITATION LIMITS
(continued)

Carbon Tetrachloride	5	5
Vinyl Acetate	10	10
Bromodichloromethane	5	5
1,1,2,2,-Tetrachloroethane	5	5
1,2-Dichloropropane	5	5
trans-1,3-Dichloropropene	5	5
Trichloroethene	5	5
Dibromochloromethane	5	5
1,1,2-Trichloroethane	5	5
Benzene	5	5
cis-1,3-Dichloropropene	5	5
Bromoform	5	5
2-Hexanone	10	10
4-Methyl-2-pentanone	10	10
Tetrachloroethene	5	5
Toluene	5	5
Chlorobenzene	5	5
Ethyl Benzene	5	5
Styrene	5	5
Total Xylenes	5	5

Quantitation Limits*

TABLE 7.1

PHASE I SOIL, SEDIMENT, AND WATER SAMPLING PARAMETERS
AND DETECTION/QUANTITATION LIMITS
(continued)

Semivolatiles	Water µg/ℓ	Soil/Sediment µg/Kg
Phenol	10**	330
bis(2-Chloroethyl)ether	10**	330
2-Chlorophenol	10**	330
1,3-Dichlorobenzene	10	330
1,4-Dichlorobenzene	10	330
Benzyl alcohol	10	330
1,2-Dichlorobenzene	10	330
2-Methylphenol	10	330
bis(2-Chloroisopropyl)ether	10	330
4-Methylphenol	10	330
N-Nitroso-di-n-propylamine	10	330
Hexachloroethane	10	330
Nitrobenzene	10**	330
Isophorone	10	330
2-Nitrophenol	10	330
2,4-Dimethylphenol	10	330
Benzoic acid	50	1600
bis(2-Chloroethoxy)methane	10	330
2,4-Dichlorophenol	10	330
1,2,4-Trichlorobenzene	10	330
Naphthalene	10	330
4-Chloroaniline	10	330
Hexachlorobutadiene	10	330
4-Chloro-3-methylphenol (para-chloro-meta-cresol)	10	330

TABLE 7.1

PHASE I SOIL, SEDIMENT, AND WATER SAMPLING PARAMETERS
AND DETECTION/QUANTITATION LIMITS
(continued)

2-Methylnaphthalene	10	330
Hexachlorocyclopentadiene	10	330
2,4,6-Trichlorophenol	10	330
2,4,5-Trichlorophenol	50	1600
2-Chloronapthalene	10	330
2-Nitroaniline	50	1600
Dimethylphthalate	10	330
Acenaphthylene	10	330
2,6-Dinitrotoluene	10	330
3-Nitroaniline	50	1600
Acenaphthene	10	330
2,4-Dinitrophenol	50	1600
4-Nitrophenol	50	1600
Dibenzofuran	10	330
2,4-Dinitrotoluene	10	330
Diethylphthalate	10	330
4-Chlorophenyl-phenyl ether	10	330
Fluorene	10	330
4-Nitroaniline	50	1600
4,6-Dinitro-2-methylphenol	50	1600
N-nitrosodiphenylamine	10	330
4,-Bromophenyl-phenylether	10	330
Hexachlorobenzene	10**	330
Pentachlorophenol	50	1600
Phenanthrene	10	330

TABLE 7.1

PHASE I SOIL, SEDIMENT, AND WATER SAMPLING PARAMETERS
AND DETECTION/QUANTITATION LIMITS
(continued)

Anthracene	10	330
Di-n-butylphthalate	10	330
Fluoranthene	10	330
Pyrene	10	330
Butylbenzylphthalate	10	330
3,3'-Dichlorobenzidine	20**	660
Benzo(a)anthacene	10	330
Chrysene	10	330
bis(2-Ethylhexyl)phthalate	10	330
Di-n-octylphthalate	10	330
Benzo(b)fluoranthene	10	330
Benzo(k)fluoranthene	10	330
Benzo(a)pyrene	10	330
Indeno(1,2,3-cd)pyrene	10	330
Dibenz(a,h)anthracene	10	330
Benzo(g,h,i)perylene	10	330

	Quantitation Limits*	
Target Compound List - Pesticides/PCBs	Water (µg/l)	Soil/Sediment (µg/kg)
alpha-BCH	0.05	8.0
beta-BCH	0.05	8.0
delta-BCH	0.05	8.0
gamma-BCH (Lindane)	0.05	8.0
Heptachlor	0.05**	8.0

TABLE 7.1

PHASE I SOIL, SEDIMENT, AND WATER SAMPLING PARAMETERS AND DETECTION/QUANTITATION LIMITS
(continued)

Aldrin	0.05**	8.0
Heptachlor epoxide	0.05**	8.0
Endosulfan I	0.05	8.0
Dieldrin	0.10	16.0
4,4'-DDD	0.10	16.0
Endrin	0.10	16.0
Endosulfan II	0.10	16.0
4,4'-DDE	0.10	16.0
Endosulfan sulfate	0.10	16.0
4,4'-DDT	0.10	16.0
Methoxychlor	0.5	80.0
Endrin ketone	0.10	16.0
alpha-Chlordane	0.5**	80.0
gamma-Chlordane	0.5**	80.0
Toxaphene	1.0	160.0
Arochlor-1016	0.5**	80.0
Arochlor-1221	0.5**	80.0
Arochlor-1232	0.5**	80.0
Arochlor-1242	0.5**	80.0
Arochlor-1248	0.5**	80.0
Arochlor-1254	1.0**	160.0
Arochlor-1260	1.0**	160.0

Required Detection Limits*

TABLE 7.1

PHASE I SOIL, SEDIMENT, AND WATER SAMPLING PARAMETERS
AND DETECTION/QUANTITATION LIMITS
(continued)

Radionuclides	Water (pCi/ℓ)	Soil/Sediment (pCi/g)
Gross Alpha	2	4 dry
Gross Beta	4	10 dry
Uranium 233+234, 235, and 238 (each species)	0.6	0.3 dry
Americium 241	0.01	0.02 dry
Plutonium 239+240	0.01	0.03 dry
Tritium	400	400 (pCi/-ml)
Cesium 137	1	0.1 dry
Strontium 89+90	1	1 dry

Parameters Exclusively for Groundwater Samples	Detection Limits* Water (mg/ℓ)
Anions	10
Carbonate	10
Bicarbonate	5
Chloride	5
Sulfate	5
Nitrate as N	

TABLE 7.1

PHASE I SOIL, SEDIMENT, AND WATER SAMPLING PARAMETERS
AND DETECTION/QUANTITATION LIMITS
(continued)

Field Parameters	
pH	0.1 pH unit
Specific Conductance	1
Temperature	
Dissolved Oxygen	0.5
Barometric Pressure	
Indicators	
Total Dissolved Solids	5

*Detection and quantitaion limits are highly matrix dependent. The limits listed here are the minimum achievable under ideal conditions. Actual limits may be higher.

**The laboratory Practical Quantification Limits (PQLs) for these analytes exceed ARARs.

TABLE 7.2

SAMPLE CONTAINERS, SAMPLE PRESERVATION, AND SAMPLE HOLDING TIMES FOR WATER SAMPLES

Parameter	Container	Preservative	Holding Time
Liquid - Low to Medium Concentration Samples			
Organic Compounds:			
Purgeable Organics (VOCs)	2 x 40-mℓ VOA vials with teflon-lined septum lids	Cool, 4°C[a] with HCL to pH<2	7 days 14 days
Extractable Organics (BNAs), Pesticides and PCBs	1 x 4-ℓ amber[b] glass bottle	Cool, 4°C	7 days until extraction, 40 days after extraction
Inorganic Compounds:			
Metals (TAL)	1 x 1-ℓ polyethylene bottle	Nitric acid pH<2; Cool, 4°C	180 days[c]
Cyanide	1 x 1-ℓ polyethylene bottle	Sodium hydroxide[d] pH>12; Cool, 4°C	14 days
Anions	1 x 1-ℓ polyethylene bottle	Cool, 4°C	14 days
Sulfide	1 x 1-ℓ polyethylene bottle	1 mℓ-zinc acetate sodium hydroxide to pH>9; Cool, 4°C	7 days
Nitrate	1 x 1-ℓ polyethylene bottle	Cool, 4°C	48 hours
Total Dissolved Solids (TDS)	1 x 1-ℓ polyethylene bottle	Cool, 4°C	48 hours
Radionuclides	1 x 1-ℓ polyethylene bottle	Nitric acid pH<2;	180 days

TABLE 7.2

SAMPLE CONTAINERS, SAMPLE PRESERVATION, AND SAMPLE HOLDING TIMES FOR WATER SAMPLES
(continued)

[a] Add 0.008% sodium thiosulfate ($Na_2S_2O_3$) in the presence of residual chlorine.

[b] Container requirement is for any or all of the parameters given.

[c] Holding time for mercury is 28 days.

[d] Use ascorbic acid only if the sample contains residual chlorine. Test a drip of sample with potassium iodine-starch test paper; a blue color indicates need for treatment. Add ascorbic acid, a few crystals at a time, until a drop of sample produces no color on the indicator paper. Then add an additional 0.6g of ascorbic acid for each liter of sample volume.

TABLE 7.3

SAMPLE CONTAINERS, SAMPLE PRESERVATION, AND SAMPLE HOLDING TIMES FOR SOIL SAMPLES

Parameter	Container	Preservative	Holding Time
Soil or Sediment Samples - Low to Medium Concentration			
Organic Compounds:			
Purgeable Organics (VOCs)	1 x 4-oz wide-mouth teflon-lined glass vials	Cool, 4°C	7 days 14 days
Extractable Organics (BNAs), Pesticides and PCBs	1 x 8-oz wide-mouth teflon-lined glass vials	Cool, 4°C	7 days until extraction, 40 days after extraction
Inorganic Compounds:			
Metals (TAL)	1 x 8-oz wide-mouth glass jar	Cool, 4°C	180 days[1]
Cyanide	1 x 8-oz wide-mouth glass jar	Cool, 4°C	14 days
Sulfide	1 x 8-oz wide-mouth glass jar	Cool, 4°C	28 days
Nitrate	1 x 8-oz wide-mouth glass jar	Cool, 4°C	48 hours
Radionuclides	1 x 1-ℓ wide-mouth glass jar	None	45 days

[1]Holding time for mercury is 28 days.

TABLE 7.4

FIELD QC SAMPLE FREQUENCY

Sample Type	Type of Analysis	Media	
		Solids	Liquids
Duplicates	Organics	1/10	1/10
	Inorganics	1/10	1/10
	Radionuclides	1/10	1/10
Field Preservation Blanks	Organics	NA	NA
	Inorganics	NA	1/20
	Radionuclides	NA	1/20
Equipment Blanks	Organics	1/20	1/20
	Inorganics	1/20	1/20
	Radionuclides	1/20	1/20
Trip Blanks	Organics	NR	1/20
	Inorganics	NR	NR
	Radionuclides	NR	NR

NA = Not Applicable
NR = Not Required
1/10 = one QC sample per ten samples collected

TABLE 7.5

SUMMARY OF ACTIVITIES
PHASE I RFI/RI OU4

Activity	Purpose	Location	No. of Locations	Method	Analysis	Sample Frequency
OU-WIDE INVESTIGATIONS						
Review new data	• Evaluate/incorporate new data	OU-wide	NA	NA	NA	1
Radiological survey	• Identify areas of radionuclide contamination	OU-wide (see Figure 7-1)	350	Ludlum 12-1A FO.16	NA	1
Surficial soil sampling	• Characterize soil contamination	OU-wide (see Figure 7-1)	35	GT.8 CDH with 10-20% grab	TAL Metals Uranium 233/235, 235, 236, 238 Plutonium & Americium Cesium 137 Strontium 90 Gross Alpha & Beta Tritium Nitrate	1 per location
ORIGINAL SOLAR POND AREA						
Visual inspection	• Evaluate impacts of building & piping on field activities	Original pond area	NA	NA	NA	1
Geophysical investigation	• Locate original ponds • Distinguish between unconsolidated/consolidated material • Locate buried lines & structures	Original pond area	Grid to be determined	GPR	NA	1

TABLE 7.5

SUMMARY OF ACTIVITIES
PHASE I RFI/RI OU4
(continued)

Activity	Purpose	Location	No. of Locations	Method	Analysis	Sample Frequency
Drill & sample borings	• Characterize lithologies • Characterize soil chemistry • Identify old clay liner • Identify depth to groundwater and bedrock • Identify migration pathways	Original pond area	4	GT.1 GT.2	Nitrate TAL Metals Uranium 233/234, 235, 236, 238 Plutonium & Americium Cesium 137 Strontium 90 Gross Alpha & Beta Tritium TCL Volatile Organics TCL Semivolatile Organics Inorganics Pesticides	Each Location: Chemistry: Minimum of surface plus 5-foot intervals to groundwater Soil: Continuous
Vadose zone monitoring	• Determine infiltration characteristics • Identify perched water horizons • Characterize vadose water quality	Original pond area	TBD	TBD	TBD	TBD
EXISTING SOLAR PONDS						
Visual inspection	• Evaluate impacts of structure & topography on field activities	Existing solar ponds	NA	NA	NA	1
Geophysical investigation	• Locate buried lines & structures • Distinguish between unconsolidated/consolidated material	Existing solar ponds	Grid to be determined pending success in original solar pond area	GPR	NA	1

TABLE 7.5

SUMMARY OF ACTIVITIES
PHASE I RFI/RI OU4
(continued)

Activity	Purpose	Location	No. of Locations	Method	Analysis	Sample Frequency
Drill & sample borings	• Characterize lithologies • Characterize soil chemistry • Identify patterns of leakage • Identify migration pathways • Identify depth to groundwater and bedrock	Existing ponds • 207A • 207BN • 207BC • 207BS • 207C • Perimeters	26 total 5 3 3 3 3 9	GT.1 GT.2	Nitrate TAL Metals Uranium 233/234, 235, 236, 238 Plutonium & Americium Cesium 137 Strontium 90 Gross Alpha & Beta Tritium TCL Volatile Organics TCL Semivolatile Organics Inorganics Pesticides	Each Location: Chemistry: Minimum of surface plus 5-foot intervals to groundwater Soil: Continuous
Vadose zone monitoring	• Determine infiltration characteristics • Identify perched water horizons • Characterize vadose water quality	Existing ponds • Perimeters	TBD	TBD	TBD	TBD
INTERCEPTOR TRENCH SYSTEM (ITS) & REMAINDER OF SITE						
Visual inspection	• Evaluate impacts of structures & topography on field activities	ITS area & remainder of site	NA	NA	NA	1
Review as-built drawings	• Evaluate extent to which ITS is keyed into bedrock		NA	NA		

TABLE 7.5

SUMMARY OF ACTIVITIES
PHASE I RFI/RI OU4
(continued)

Activity	Purpose	Location	No. of Locations	Method	Analysis	Sample Frequency
Drill & sample borings	• Characterize lithologies • Characterize soil chemistry • Identify migration pathways • Identify depth to groundwater & bedrock • Evaluate extent to which ITS is keyed into bedrock • Evaluate extent of Arapahoe sandstone subcrop • Observe bedrock fracturing, if present	ITS area & remainder of site • ITS area • Solar pond area • Deep borings (subset of above)	19 total 10 9 6	GT.1 GT.2	Nitrate TAL Metals Uranium 233/234, 235, 236, 238 Plutonium & Americium Cesium 137 Strontium 90 Gross Alpha & Beta Tritium TCL Volatile Organics TCL Semivolatile Organics Inorganics Pesticides	Each Location: Chemistry: Minimum of surface plus 5-foot intervals to groundwater Soil & Rock: Continuous
Install piezometer nests	• Evaluate hydraulic capture of ITS	ITS	4	GT.6 GW.1	NA	NA
Vadose zone monitoring	• Correlate perched water horizons with down-slope seeps	Solar pond area	TBD	TBD	TBD	TBD

TBD -- To be determined
NA -- Not applicable